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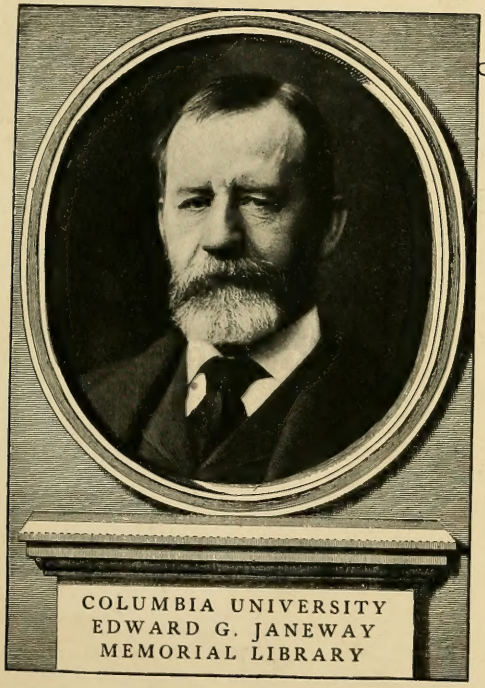

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# FRACTURES

# MEDICAL AND SURGICAL THERAPY

EDITED BY

SURGEON-GENERAL SIR ALFRED KEOGH
K.C.B., C.B., LL.D., M.D., ETC.

FOREWORD BY

WILLIAM C. GORGAS
SURGEON-GENERAL U. S. A.

## VOLUME IV

## FRACTURES

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# FRACTURES

TREATMENT
OF FRACTURES

FRACTURES OF
THE LOWER JAW

FRACTURES OF
THE ORBIT

BY

R. LERICHE
L. IMBERT
PIERRE REAL
FELIX LAGRANGE

D. APPLETON AND COMPANY
NEW YORK AND LONDON
1918

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# CONTENTS

## SECTION I

## TREATMENT OF FRACTURES

BY

R. LERICHE


| | | PAGE |
|---|---|---|
| CHAPTER I. | GENERAL CONSIDERATIONS UPON WOUNDS OF JOINTS, THEIR GRAVITY AND THEIR TREATMENT | 1 |
| | Gravity of Wounds of Joints | 1 |
| | General Treatment of Wounds of the Synovial Membrane and of Compound Fractures into Joints | 8 |
| | General Technique of Operations upon the Joints | 18 |
| I (*Continued*) | GENERAL SURVEY OF PRESENT METHODS FOR OBTAINING WOUND ASEPSIS | 34 |
| | The Carrel-Dakin Method | 37 |
| | Dakin Solution Without Boric Acid | 40 |
| | Dakin Solution With Boric Acid | 41 |
| | Titration of the Solution (Lyle) | 42 |
| | Equipment | 42 |
| | Employment of Hypochlorite Solutions | 45 |
| | Dichloramin-T in Oil Method | 58 |

PAGE

"Javelle Water" in the Treatment of War Wounds . . . . . 65
Hypochlorous Acid Preparations—Eusol and Eupad . . . . . 67
Hypertonic Solutions (Lymphagogic Agents) . . . . . 71
Salt Pack Method of Wound Treatment . . . . . 72
Magnesium Chloride . . . . . 74
Sugar Treatment of Wounds . . . 75
Collargol . . . . . 76
Bipp (Rutherford Morison's Method) . . . . . 77
Iodated Starch . . . . . 80
Flavine (Acri- and Pro-flavine) . . 80
Brilliant Green, Paste and Lotion 83
Methyl Violet . . . . . 86
Magnesium Sulphate . . . . . 86
Vincent's Powder . . . . . 88
Sunlight and Ozone Treatment of Infected Wounds . . . . . 90
Acetozone . . . . . 93
Delbet's Pyoculture . . . . . 94
Vaccine and Serum Treatment of Infected Wounds . . . . . 95
Donaldson's Method (Introduction of Living Anærobes) . . . 100

CHAPTER II. WOUNDS AND FRACTURES OF THE SHOULDER . . . . . 102
Anatomical Types and Clinical Course . . . . . 102
Primary Therapeutic Indications . 105
Operative Technique . . . . . 112
Post-Operative Treatment . . . . 117

PAGE

Evacuation of Patients with Shoulder Wounds . . . . . 124
Treatment of Patients Seen Late or After Evacuation . . . . . 125

CHAPTER III. WOUNDS AND FRACTURES OF THE ELBOW . . . . . 129
Anatomical Types and Clinical Course . . . . . 129
Primary Therapeutic Indications. 134
Operative Technique . . . . . 149
After-Treatment . . . . . 154
Evacuation of Patients with Elbow Wounds. . . . . 160
Treatment of Patients Seen Late or After Evacuation . . . . . 162

CHAPTER IV. WOUNDS AND FRACTURES OF THE WRIST . . . . . 170
Anatomical Types and Clinical Course . . . . . 170
Primary Therapeutic Indications. 171
Operative Technique . . . . . 175
Post-Operative Treatment. . . . 177
Evacuation of Patients with Wrist Wounds. . . . . 180
Treatment of Patients Seen Late or After Evacuation . . . . . 180

CHAPTER V. WOUNDS AND FRACTURES OF THE HIP. . . . . 184
Anatomical Types and Clinical Course . . . . . 184
Primary Therapeutic Indications. 187
Operative Technique . . . . . 190

PAGE

Post-Operative Treatment . . . . 193
Evacuation of Patients with Hip Wounds . . . . . 197
Treatment of Patients Seen Late or After Evacuation . . . . . 197

CHAPTER VI. WOUNDS AND FRACTURES OF THE KNEE . . . . . 201
Anatomical Types and Clinical Course . . . . . 201
Primary Therapeutic Indications . 206
Operative Technique . . . . . 216
Post-Operative Treatment . . . . 218
Evacuation of Patients with Knee Wounds . . . . . 225
Treatment of Patients Seen Late or After Evacuation . . . . . 225

CHAPTER VII. WOUNDS AND FRACTURES OF THE ANKLE . . . . . 234
Anatomical Types and Clinical Course . . . . . 234
Primary Therapeutic Indications . 238
Operative Technique . . . . . 245
Post-Operative Treatment . . . . 248
Evacuation of Patients with Ankle Wounds . . . . . 252
Treatment of Patients Seen Late or After Evacuation . . . . . 252

CHAPTER VIII. WOUNDS AND FRACTURES OF THE ANTERIOR TARSUS AND THE FORE-PART OF THE FOOT . . . 255
Anatomical Types and Clinical Course . . . . . 255
Primary Therapeutic Indications . 256

PAGE

Operative Technique . . . . . 262
Post-Operative Treatment. . . . 266
Evacuation of Patients with Anterior Tarsal Wounds. . . . . 268
Treatment of Patients Seen Late or After Evacuation . . . . . 268

CHAPTER IX. MULTIPLE JOINT WOUNDS. . . . . 272

CHAPTER X. A GENERAL STUDY OF SHAFT FRACTURES. . . . . 277
Pathological Anatomy of the Seat of a Fracture in Its Earliest Stage . . . . . 280
Immediate Results of Fracture, and the Normal Course to Recovery . . . . . 292
Pathological Changes in a Fracture. . . . . 294

CHAPTER XI. GENERAL PRINCIPLES IN THE CONSERVATIVE TREATMENT OF FRACTURES. . . . . 313
Operative Disinfection of Open Fractures . . . . . 314
Initial Operative Disinfection of Fractures in the First Few Hours: Exploratory and Prophylactic Esquillectomy. . . 315
Secondary Operative Disinfection of Clinically Infected Fractures: Esquillectomy and Drainage: Total Subperiosteal Esquillectomy . . . . . 328
General Indications for the Operation . . . . . 331

PAGE

Technique of Sub-periosteal Esquillectomy . . . . . 343
The Reduction of Gunshot Fractures . . . . . 353
The Immobilisation of Fractures . 362

Chapter XII. Fractures of the Humerus . . . 385
Fracture of the Neck of the Humerus (Sub-epiphyseal Fracture) 385
Sub-deltoid Fracture . . . . . 400
Fracture of the Middle of the Shaft . . . . . 406
Supra-condylar Fracture of the Elbow. . . . . 433

Chapter XIII. Fractures of the Forearm . . . 439
Fractures of Both Bones of the Forearm. . . . . 441
Fractures Just Below the Elbow Joint . . . . . 441
Fractures of the Shafts . . . . 446
Fractures Just Above the Wrist. 460
Fractures of the Radius Alone . . 465
Fracture of the Shaft . . . . . 465
Fracture of the Lower Radial Epiphysis . . . . . 476
Fractures of the Ulna. . . . . 484

Chapter XIV. Multiple Fractures of the Upper Limb . . . . . 490

Chapter XV. Fractures of the Femur . . . . 494
Sub-Trochanteric Fracture. . . . 494
Fractures of the Shaft; the So-called Fractures of the Thigh . 507
Supra-Condylar Fractures . . . . 547

PAGE

CHAPTER XVI. FRACTURES OF THE LEG . . . . . 554
Fracture of Both Bones of the Leg. 554
Fracture of the Tibia. . . . . 574
Fracture of the Fibula . . . . . 577

CHAPTER XVII. MULTIPLE FRACTURES OF THE LOWER LIMB . . . . . 581

## SECTION II

## FRACTURE OF THE LOWER JAW

BY

L. IMBERT AND P. REAL

CHAPTER I. INTRODUCTION . . . . . 585
CHAPTER II. ETIOLOGY . . . . . 597
CHAPTER III. PATHOLOGICAL ANATOMY . . . . . 599
Incomplete Fracture . . . . . 600
Complete Fracture . . . . . 602
Large Loss of Bony Substance. Shattering. . . . . 622
Large Loss of Substance of the Soft Parts . . . . . 623
Anatomical Development . . . . 623
CHAPTER IV. SYMPTOMS AND DIAGNOSIS . . . . 629
Recent Fracture . . . . . 633
Old Fracture. . . . . 640
Fracture of the Angle. . . . . 641
Fracture of the Ramus . . . . . 642
The Use of Radiography in Mandubular Fracture. . . . . 642
Closure of the Jaws. . . . . 645
Clinical Development. . . . . 649
CHAPTER V. MECHANICAL TREATMENT . . . . . 659
Elementary Principles. . . . . 659

PAGE

The Immediate Treatment of Lesions . . . . . 662
Mechanical Treatment of Fractures . . . . . 666
Treatment of Pseudo-Arthrosis. . 710
Treatment of Malocclusion . . . 727
Mechanico-Therapeutic Treatment of Myotonic Construction of the Maxillæ. . . . . 730

CHAPTER VI. SURGICAL TREATMENT . . . . . 734
Osteo-Synthesis . . . . . 735
Operative Technique . . . . . 736
Results of Osteo-Synthesis. . . 748
Bony and Cartilaginous Grafts. Actual Results. . . . . 751

CHAPTER VII. ASSESSMENT OF THE DISABLEMENTS CONSEQUENT UPON FRACTURE OF THE MANDIBLE . . . . . 763
Loss of Teeth, Complicated by Fracture of the Alveolar Border but Without Complete Fracture 765
Fractures . . . . . 767
Closure of the Jaws. . . . . 771

## SECTION III

## FRACTURES OF THE ORBIT

BY

FELIX LAGRANGE

CHAPTER I. HISTORICAL . . . . . 777
CHAPTER II. THE ORBITAL CAVITY . . . . . 788
Conformation . . . . . 788

PAGE

Resistance to Injury . . . . . 794
Vulnerability of the Orbit . . . . 798

CHAPTER III. GENERAL CONSIDERATIONS UPON THE ATIOLOGY OF FRACTURES OF THE ORBIT . . . . . 802
Fractures of the Orbit. . . . . 802
Pathogenesis. . . . . 807

CHAPTER IV. FRACTURES OY THE ORBIT WITH PRESERVATION OF THE EYEBALL 813
The Laws Governing the Affections of the Visual Apparatus in Injuries of the Orbit with Preservation of the Orbit . . . . . 813
Pathology of the Visual Disorders 849
Description of the Visual Defects. 853
Symptoms and Diagnosis . . . . 934

CHAPTER V. FRACTURES OF THE ORBIT WITH DESTRUCTION OF THE EYEBALL . . 938
Fractures Implicating the Neighbouring Cavities . . . . . 946

CHAPTER VI. TREATMENT OF FRACTURES OF THE ORBIT AND THEIR COMPLICATIONS 970
Superior Orbital Margin and Wall 971
Fractures of the Internal Margin and Wall . . . . . 973
Fractures of the Inferior Margin and Wall . . . . . 973
Fractures of the External Margin and Wall . . . . . 974

CHAPTER VII. TREATMENT OF OCULAR COMPLICATIONS . . . . . 983
Sympathetic Ophthalmia . . . . 983

PAGE

Traumatic Cataract. . . . . 988
Retinal Detachment . . . . . 990

Chapter VIII. Reparative Surgery of Orbital Fractures . . . . . 993
Restoration of the Eyelids. . . . 993
Restoration of the Conjunctival Culs-de-sac . . . . . 994
Repair of Damage to the Orbital Walls and in the Bone . . . . 997

Conclusions. . . . . .1015
List of Case Reports . . . . . .1019
Index. . . . . .1021

# SECTION I

# TREATMENT OF FRACTURES

# THE
# TREATMENT OF FRACTURES

## PART I

## FRACTURES INVOLVING JOINTS

### CHAPTER I

### GENERAL CONSIDERATIONS UPON WOUNDS OF JOINTS, THEIR GRAVITY AND THEIR TREATMENT

#### I. Gravity of Wounds of Joints

Wounds of the joints, which in civil practice have always had the reputation of being very serious, are among the most formidable injuries which the surgeon at the front is called upon to treat. It may be added with truth that they are perhaps those for which most can be done if he intervenes in time.

Their gravity is due to three causes.

(*a*) The projectile which strikes the patient carries with it some particles of clothing which it deposits in the joint whether it remains there itself or whether it passes out again. These particles carry various germs which there find conditions perfectly suited to their rapid development, since they are shut up in a closed cavity sheltered from everything which might hinder their growth.

(*b*) The damaged synovial membrane, which is highly absorbent, has numerous folds and recesses in which the virulence of the microbes increases the more rapidly because the recesses are shut off from the exterior, and hence the microbes are not amenable to exposure to the air, which is essential in the treatment of all septic wounds.

(*c*) The synovial injury is almost always complicated by a fracture of the articular surface. Doubtless pure synovial injuries are to be found, either with or without the presence of the missile. In the knee such a condition is not rare, but everywhere else, even in the shoulder, it is quite exceptional; practically, a joint injury is almost synonymous with a fracture of the joint. Even in the knee bony injury is always to be expected and considerably aggravates the prognosis; arthritis is then conjoined with osteomyelitis, for the fissures extending up into the shaft carry the infection for a long distance, and if the patient escapes severe early infection he is very likely to die of chronic septicæmia.

Only one type of joint wounds remains almost always uncomplicated by these formidable conditions: the bullet wounds with punctiform openings run a course similar to that of injuries not exposed to the air. A long-range bullet of high velocity only makes an almost imperceptible skin wound, meets the body point foremost, passing through the clothing without taking anything with it, and perforates the tissues without producing the great explosive damage which bullets fired at short range so often do. The wounds thus made generally remain aseptic.

In all other cases there is nearly always grave joint sepsis which develops in one of the following three principal types:

First Type of Joint Infection.—The sepsis spreads with frightful rapidity. In a few hours the temperature reaches 40° C. (104° F.), the general con-

dition is bad; the patient appears profoundly toxic. The joint is distended and very painful, and the whole limb is œdematous. Death ensues in three or four days from septicæmia, with or without gangrene; secondary amputation or disarticulation rarely saves one-third, certainly not one-half of the patients.

Second Type of Joint Infection.—One sees here the development of septic local phenomena of increasing gravity. The limb presents marked œdematous swelling, the joint is swollen, hot, and very painful; the least movement makes the patient cry out, and there are foul sloughs on the wound and a sero-purulent discharge oozes from the wound of entry, about which there is often localised gas crepitation. The temperature oscillates markedly and the general condition is profoundly depressed. One operation after another may be performed, each too late. If the knee, the hip, or even the shoulder be the joint concerned, the mortality is high in spite of amputation; the case runs its course in from eight to ten days.

Third Type of Joint Infection.—Here the injuries are limited. There is copious suppuration with purulent tracks communicating with the joint; if nothing be done, a chronic septicæmia supervenes. In the case of the shoulder, the elbow, and the ankle, repeated incisions and the removal of bony fragments generally succeed in keeping the complications under and the patient slowly gets well with an ankylosed joint. In the case of the knee and the hip, amputation and death are frequent. Patients who have apparently recovered are liable to numerous risks, such as recurrent articular osteitis, bone abscesses, and persistent sinuses.

This last clinical type is the one seen almost exclusively at the base; it and the bullet wounds with small openings comprise the forms of joint wounds most frequently seen by many, and that is why some surgeons at the base hospitals have got it into their heads

that wounds of joints are not grave. No view could be falser or more dangerous, for it leads to the advocacy of treatment at the front which is inadequate for the severely wounded, and to the proscription of the really conservative methods as being too severe.

It can never be too often repeated that it is a long way from the aid-post to the base hospital; those who arrive at the latter with an articular fracture are only those who have been able to bear the journey; the worst cases have been left behind at various stages along the route. To take account only of those who arrive at the base is to omit two-thirds of them at least.

This is directly proved by statistics.

In examining the figures of the wounded who were evacuated from the aid-posts of one division during the winter of 1914, I made a point of noting the different degrees of gravity of the wounds which I saw, and here are the results. Of 614 wounds of the upper limbs, 457 were considered fit for immediate evacuation; 157 called for immediate intervention.

Of 601 wounds of the lower limbs, 451 were apparently slight, and 150 required operation on the spot.

Thus, out of 1,215 wounds of limbs, 908 were evacuated from the front and 307, or a quarter, did not leave the ambulances in the immediate battle area.

The 908 who were considered fit to be evacuated during the first few hours after being wounded only quitted the army zone the evening of the next day, after a whole day's journey and after having passed through three successive surgical lines, where a great number of them were retained because their wounds had become aggravated or their pain had become worse. Those who reached a base hospital after a two or three days' journey were only slight cases in comparison with those who had been left behind en route.

Among the 307 wounded who required immediate surgical intervention, there were obvious joint injuries in more than a third. It will thus be seen what reliance is to be placed upon the opinion of those at the base who think that they receive wounded *straight from the front.*

Here are a few more figures :

At the beginning of November my ambulance received in thirty hours 489 wounded comprising 251 injured limbs, of which 178 were caused by bullets and only 83 by shell-splinters.

Of 138 wounds of the upper limbs, 36 were detained (29 bullet wounds, 7 by shell-splinters), and 102 were considered fit for evacuation from the zone of the divisional ambulances (74 bullet wounds, 28 by shell-splinters).

Of 123 wounded in the lower limbs, 79 were evacuated (58 bullet wounds, 21 by shell-splinters) and 44—more than one-third—were detained (27 bullet wounds, 17 by shell-splinters). Half of the wounded detained had evident joint injuries.

On the night of December 24-25 we received 150 wounded. Among 43 having injuries of the upper limbs, 15—*i.e.* 28 %—presented fractures of the shaft or articular ends, and were treated on the spot. Among 27 having injuries of the lower limbs, 13—or almost 50 %—presented fractures of the shaft or articular ends, and were not evacuated. These few figures enable one to understand how greatly mistaken is the calculation of those who judge the real gravity of joint fractures by what they see at the base.

In dealing with war-surgery it is always necessary to be precise as to where the operation is performed when one talks of the nature of the surgical procedure, for there is a fundamental difference in the gravity of the wounds seen at a station situated half an hour's journey from the line of fire and those seen twenty-five miles behind ; and much more between those received

by the divisional ambulance and those which arrive at a base hospital after two or three days of successive transfers. Since the conditions are not similar, treatment that would appear conservative at the base is not so at the front because it would be insufficient, while an operation that would be thought conservative at the front might appear too radical at the base.

It is owing to their inability to draw this necessary distinction that some surgeons have proclaimed the failure of conservative surgery, while others, with a like conviction, have been able to recommend systematic abstention from operation and advise immobilisation pure and simple, as was advocated in military surgery before the present war.

For the surgeon at the front who has to sort out his patients without delay, articular fractures fall into three large groups :

1. Crushing of a Limb in the neighbourhood of a Joint.—Here there is a smashing-up of the bones and joint accompanied by extensive destruction of muscles and irreparable vasculo-nervous injuries, for which amputation or disarticulation is alone of any use. The best time to perform the operation is the only matter open to discussion in these cases.

The injured arrive in a condition of extreme shock. None of them are evacuated from the front line; unless there is an enormous number of cases, none are passed through to the 2nd Ambulance station, much less the clearing-station ; they do not get past the first surgical line (*relai*). Whatever be the treatment, whether by immediate or delayed amputation, the mortality is considerable. This might perhaps be diminished by performing transfusion of blood before operation, if this were possible, and it might well be tried.

But to conditions such as these the name of joint-wounds is inapplicable, and to include them in the same category as those in which the joint injuries are

more or less uncomplicated is to create confusion. It will not be done here.

2. Comminuted Articular Fractures with or without fissures radiating into the shaft, but with the main vessels and nerves intact.—This is the group comprising wounds of medium severity which form the great majority of joint fractures. There are all degrees between the complete destruction of a joint on the one hand and the simple parietal fracture of an articular end on the other. The treatment of these will be discussed almost exclusively in this book. In the case of each articulation I shall consider the treatment of a joint wound without fracture, with or without the missile present.

3. Bullet Wounds of Joints with a Punctiform Skin Wound, with or without fracture.—These behave like simple fractures and are quite mild in character, provided that rigorous immobilisation is secured. They are really punctured wounds of the synovial membrane, simple trochar-like wounds of the bone with or without radiating fissures of the shaft, and they result from long-range bullet-wounds.

In the case of the knee, a copious hæmarthrosis often requires one or more aspirations which it is well to make quite early. Otherwise prolonged immobilisation alone suffices for cure, but it must be kept up for a long time and movement must only be commenced when all pain has completely disappeared.

I have had 12 cases of this kind—7 of the knee, 3 of the shoulder, and 2 of the elbow; they wore a plaster casing for from three weeks to two months. They all recovered, with very satisfactory recovery of the functions of the joint.

Briefly, these cases are of the mild type which before the war was considered the usual type of bullet wounds of joints. Their mildness is explained by the conditions under which the wound is made; the bullet enters with its pointed end foremost, passes through

the clothing between its threads without carrying any with it. It traverses the skin, the muscles, and the synovial membrane without depositing in them any infected fragments of clothing, and the fracture, whatever be its type, whether erosion, cartilaginous abrasion, furrow, gutter, or bony perforation, is an aseptic fracture, and runs its course as such without infection.

But no rule is absolute, and one can quite well understand that infection may occur in these joint wounds with tiny skin orifices. So these patients ought always to be very carefully supervised ; their temperatures should be taken regularly, the joint should be examined daily without necessarily removing the plaster each time. If after the first few days the primary fever caused by the hæmarthrosis persists, if the temperature, after having fallen to normal, suddenly goes up, if the general condition is affected, or if there is the least suspicion of infection, free arthrotomy may become necessary. I have never had occasion to perform it under these circumstances.

All the foregoing remarks about joint injuries with punctiform skin wounds refer to the injuries made by bullets. In the case of quite a minute wound caused by a small splinter of a shell or grenade, infective complications are to be feared. The wounds made under these circumstances resemble those in the second category above and will be considered with them.

### II. General Treatment of Wounds of the Synovial Membrane and of Compound Fractures into Joints

Since the crushing of limbs in the neighbourhood of joints requires amputation, and bullet wounds of joints with very small skin wounds are amenable to simple immobilisation, there is only a single category of joint wounds in which the treatment is varied and

open to discussion. It forms our second group and is a very large one.

Before seeing what it is best to do for one of these cases it is well to define the principal types which can be identified by radiography.

They are, in order of increasing anatomical gravity :

(*a*) A wound of the synovial membrane, without a bony lesion but with the projectile free inside the joint ; this is rarely seen except in the knee, and is very exceptional elsewhere (*e.g.* the shoulder).

(*b*) A wound of the synovial membrane with the projectile embedded in bone, that is to say with a fracture of the cancellous end of one bone.

(*c*) A wound of the joint with a fracture of the compact layer of the epiphysis, that is, a fracture not interrupting its continuity. In these cases there are sometimes fissures and multiple jagged splinters.

(*d*) An articular fracture properly so called, single or multiple ; here the bony lesions vary very much according to the epiphysis affected and the circumstances governing the impact of the projectile. In the case of the upper end of the humerus there may be a simple separation of the head, or complete destruction of it, a frequent type ; at the elbow there is often a T-shaped fracture with irregular fissures, recalling in certain points the fractures of civil practice ; the articular fragment is often large, the shaft being pointed like the mouth-piece of a flute. In the ulna, besides a transverse fracture of the olecranon, complete crushing of the bone into small fragments is met with. The same thing may occur in the head of the radius where large splinters are rare.

In the hip, crushing of the trochanter, with fissure through the neck, or separation of the head of the bone is frequent.

In the knee, simple fracture of one condyle or a T-shaped fracture (figs. 2 and 4) of the femur may be found ; in the tibia, it is common to find extensive

crushing of the cancellous tissue with pulverisation of bone, but without large splinters or radiating fissures (fig. 3). Radiating fissured fractures are especially often met with in the lower extremity of the humerus, in the ulna, the hip, and the lower end of the femur.

(*e*) Complete crushing of the articular end.

This classification makes it clear that one standard method of treatment is not applicable to all cases.

But the fundamental principles of treatment remain irrefutable ; they are those which govern the entire treatment of war-wounds, that is to say, the necessity of a primary clearing operation, performed as early as possible, removing missiles, fragments of clothing and organic débris on its way to rapid decomposition. There can be no question as to the absolute urgency of these preventive incisions, which are prophylactic against sepsis and are the basis of all conservative surgery.

This clearing out by incision ought to be complete, extend to all the injured parts, and leave nothing doubtful behind.

In practice there are still differences of opinion upon the best way of carrying it out and the extent to which it should go.

We have the choice of four methods—viz. arthrotomy, removal of bony fragments from the joint (esquillectomy), resection, and amputation.

These operations are in no way opposed to one another ; each has its indications, which are determined by the extent and nature of the injury as determined by radiography and by exploration. On the other hand, the indications vary according to the time that has elapsed since the infliction of the wound and according to its situation.

**A. Primary Operations (during the first twelve hours).** —Theoretically we may say that to effect with certainty the necessary prophylaxis and to make sure of a definite orthopædic result, it is necessary in the

first twelve hours to extract the missile, to remove fragments from simple parietal fractures, to resect those fractures which interfere with the mechanics of the joint, and to amputate for conditions in which the damage is incompatible with the ultimate satisfactory functional restoration of the limb.

In practice these are the rules which ought to be applied as soon as possible, certainly within twenty-four hours.

(*a*) *Missiles within the joint must be removed.*—There are no doubt some which remain clinically aseptic, but they are quite the exceptions. As a rule, a splinter of a shell or grenade, carrying with it débris of clothing, is followed with certainty by a rapidly spreading acute arthritis. The infection introduced into a closed cavity is very formidable, and a fatal result often follows. In short, the presence of a missile in a joint is always dangerous. Its removal is quite the opposite.

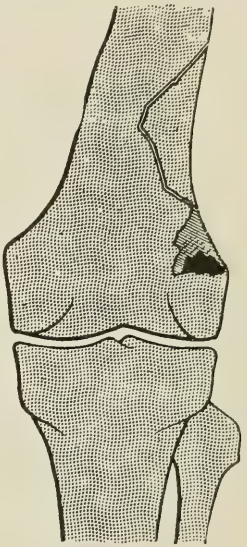


Fig. 1.—Wound of the joint with parietal fracture not interrupting the continuity of the epiphysis and amenable to a limited esquillectomy after removal of the projectile.

Simple opening-up of the wound is not sufficient to eliminate all chance of sepsis; drainage certainly diminishes the immediate risk of its development, but unless the missile be removed, the degree of infection is only lessened and the patient remains a prey to slow septicæmia which is sometimes fatal.

(*b*) *The area of a parietal fracture should be excised.*—Every bone which is fissured or frayed at the edge and all crushed cancellous tissue ought to be treated

by scooping out the bone and removing the bony splinters ; on the points of these, even after extraction of the missile, minute organic particles and threads of clothing material are held up, and the development of a focus of osteitis is a grave matter. This osteitis is the more dangerous as bony fissures often radiate from the point which was struck, and the

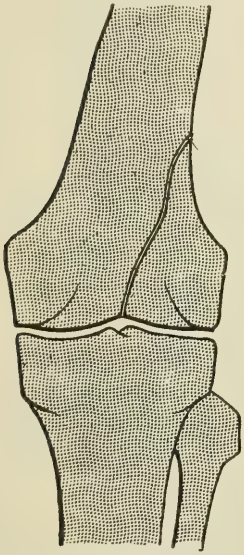


FIG. 2.—Fracture of one condyle requiring, in view of future orthopædy, resection of the knee-joint through the epiphyses.

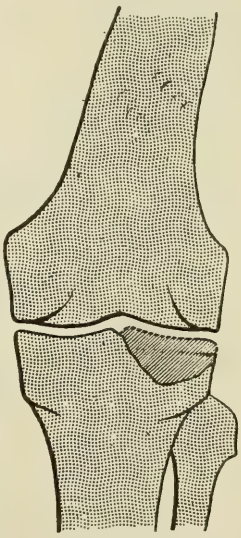


FIG. 3.—Fracture of one condyle of the tibia requiring, in view of future orthopædy, resection of the knee-joint through the epiphyses.

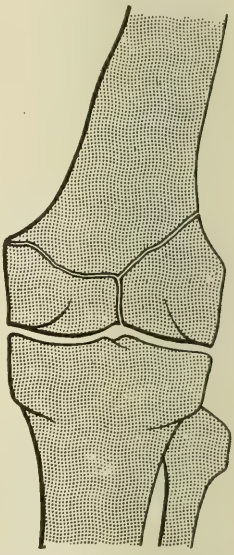


FIG. 4.—T-shaped fracture of the lower end of the femur requiring typical resection of the knee-joint.

sepsis travels along these. As a result, infection of the bone marrow occurs which amputation alone is able to remedy.

(*c*) *A fracture that will permanently interfere with the functions of a joint should be treated by immediate resection*, chiefly because that operation in the very early

period guards against infection ; and also because it provides for the future usefulness of the joint except in the case of the knee, where ankylosis ought to be systematically aimed at ; elsewhere it assures satisfactory if not entire, recovery of function, while at the knee it is the only measure that assures a position of the limb which is fundamentally necessary to walking (figs. 2–4).

But for this purpose resection must be as true to type as possible : it ought not to be merely a question, as it often is, of the mere level of the bone sections. The typical operation is that derived directly from the teaching of Ollier, and deals with the joint without sacrificing the tendons, carefully separates the periosteal prolongation of the capsule without dividing ligaments or tendons, and is followed by a most strict post-operative treatment.

(*d*) *A fracture of the lower limb extending as far down the shaft as it does towards the epiphysis should be treated by amputation*, because a cure is difficult to obtain by conservative methods and would be followed by a very bad functional result (fig. 5).

In the upper limb amputation is to be avoided at any price short of extensive excision of bone, however little hope there is of preserving a useful hand.

To these general statements we may add that:

(*a*) *Arthrotomy* in the early stage ought to be only an exploratory procedure followed by extraction of the missile, which should be localised if possible. The best method of localisation would appear to be Hirtz's "compasses," when there is time to employ them ; if stress of work will not allow of this, the position of the projectile should be ascertained by radioscopy, marked on the surface, and the joint widely opened. If radioscopy is not available, an exploratory arthrotomy should be performed so as to admit of removal.

(*b*) *Esquillectomy* (*removal of the fragments*) will be added to arthrotomy whenever the bony lesion is

confined to the surface of the bone. It should be done by a rugine followed by a curette. If the fracture is more extensive than at first appeared or than is indicated by radioscopy, if, for example, there be deep-seated cancellous crushing of one of the condyles of the femur, one would perform immediate resection; "esquillectomy" * is only of use in the small parietal fractures. They are, in my opinion, the only cases suited for this method.

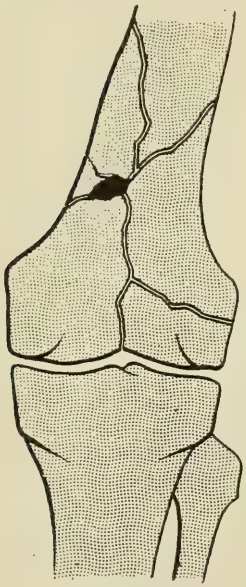


FIG. 5.—Fracture of shaft and epiphysis necessitating amputation.

Many surgeons take a different line: arthrotomy with esquillectomy is with them the treatment of choice for almost all fractures into joints, because it appears to be the most conservative method. They contrast it with resection, which they say gives bad results and look upon as a mutilating operation. According to their view, arthrotomy is done to drain an area that esquillectomy has cleared out. Thus presented, the parallel is absurd; each operation has a precise field of its own, which cannot be departed from without falsifying the results and the indications.

In the early stages of these war-wounds arthrotomy ought not to be done to drain, but to explore, so that the surgical sterilisation of the wound may be ensured by the removal of foreign bodies; if the missile in its passage has caused a partial fracture, a gutter or furrow on the articular end, if it has detached a frag-

* The term "esquillectomy" will be used throughout this translation instead of the more cumbrous term "removal of splinters of bone."—ED.

ment or splinters of bone, the removal of these also is indicated; and the same is the case when the missile has embedded itself in the bone and has produced in it a crush-fracture. But whenever there is definite solution of the continuity of an epiphysis, esquillectomy ought to give place to resection. One can doubtless recall some brilliant results from limited intra-articular esquillectomy in these complex cases, but these will always be exceptional results obtained under favourable circumstances: the method is dangerous, because patients in great numbers cannot all receive the strict supervision which is imperative for success; besides, the final orthopædic result of these partial operations is generally bad.

(*c*) *Subperiosteal resection* is the method of choice for comminuted epiphysial fractures likely to unite badly, and for all those that interfere with the mechanics of the joint. If done early, it is the typical operation for the prophylactic clearing-out which anticipates all sepsis and ensures aseptic results. When done according to the subcapsular-periosteal method, it gives remarkable results. It is used more freely in some regions than in others; at the shoulder it will sometimes be possible to do without it, subcartilaginous excision giving very favourable results. At the elbow, at the knee, at the ankle, and in the metatarsus it should, however, always be employed; in these situations it is the ideal conservative operation.

(*d*) *Immediate amputation* ought only to be chosen in exceptional cases, unless there is crushing of the bones with irreparable injury to the muscles, vessels, and nerves.

In the upper limb it ought never to be performed primarily whatever the extent of the injury, because subperiosteal resection and extensive esquillectomy always suffice to deal with even the greatest damage.

In the lower limb it is performed sometimes after direct exploratory examination.

Whatever may be the state of the elbow or the shoulder, a normal hand with mobile fingers is always of more use than a hook on the forearm. In the lower limb, on the contrary, the conditions may be such that an artificial leg is much better than a considerably shortened leg or thigh. One can hardly define these conditions in words ; it is largely a question of degree. Three factors, however, dominate the decision :

If the lesions of the soft parts are very extensive, if, in short, preservation of the limb appears too hazardous, immediate amputation should be done.

If the bony lesions are too extensive for the functional power to be ultimately restored, one would amputate at once ; in practice, any injury may be considered as too extensive that would entail a shortening of at least 4 inches.

When there is a great influx of wounded, amputation should be chosen unless the case appears very favourable for resection ; conservative surgery requires diligent post-operative supervision, much time and care. Without them it is dangerous and apt to lead to disappointing results.

**B. Secondary Operations (in the febrile period).**— In these cases there is no longer any question of practising prophylactic operations upon damaged areas threatened with imminent sepsis, but of ensuring drainage and rapid disinfection of an already infected joint. The decision as to the operative measures best fitted for this purpose is guided by the question of the resistance of the individual patient ; the longer the time since the commencement of the sepsis, the more radical should the measures be, and the less the reliance that should be placed upon drainage without removal of bone.

(1) *Arthrotomy* is suited to pure synovial injuries, to drain abscesses, and to remove if possible the foreign bodies causing the trouble. It is useful for joints

with loose capsules and large synovial cavities. It only drains close-fitting joints like the elbow and the hip indifferently. It is only successful in cases of joint suppuration due to superficial osteitis that easily finds its way to the surface. It should be employed for the shoulder and the knee, elsewhere it is not worth while wasting time upon it ; the less so since the usual result of these suppurations is ankylosis, and it is therefore better to resect at once, especially where articular mobility is desirable, as for example in the elbow.

(2) *Resection* is a method of drainage only in the close-fitting joints. In severe infections without fracture it performs marvels at the elbow, the wrist, the hip, the ankle, and the tarsal joints. Often useless at the shoulder, it is equally so at the knee, since it leaves no cavity for drainage. In simple suppurating arthritis of the knee, without injury to bone, if arthrotomy with extraction of the missile does not lead to rapid improvement of the general and local phenomena, and if at the end of three or four days the condition is still critical, resection is useless and even dangerous. Perhaps excision of the synovial membrane might be of value : I do not recommend it since I have no experience of it, and until we have more knowledge on the point we must resign ourselves to rapid amputation.

It is quite a different matter when there is a fracture. The infection is then rather an osteomyelitis than an arthritis, and it is safer to resect at once, even at the knee, to get rid of the infection. Undoubtedly failures will occur, but there will also be remarkable successes. My advice is to use it immediately for any joint unless the injury is parietal or extra-articular.

(3) *Immediate amputation* is called for when the patient's general condition is profoundly lowered, when there are purulent sinuses everywhere, and when there are multiple infected wounds ; in short, when the patient obviously requires to be rid at once of the source of the infection.

Secondary amputation should be done, without too great loss of time, for injuries of the knee after the failure of arthrotomy or resection, the risk of the septicæmia being then only too apparent. In the case of the ankle and the upper limb an attempt to preserve the limb by resection can be persisted in much longer without danger.

### III. General Technique of Operations upon the Joints

The operations which are performed on the joints, being essentially conservative, require great precision and much attention to detail from beginning to end. The different operative stages should be conservative, in order that the final result may be preservation. It is a fundamental precept, never to be forgotten, that whenever an attempt is made to obtain recovery of function, none of the elements of strength and mobility in a joint must be sacrificed.

This precept imposes two rules of technique which ought to be regarded as dogmatic.

*The exploratory incisions should not sacrifice any tendon, muscle, or muscular nerve-supply.*

*The opening up of bony cavities ought to be done with the sharp rugine, which not only separates the periosteum, but raises with it the capsular ligaments and tendinous insertions, thus leaving intact all the working apparatus of the joint.*

I place on record these two precepts of Ollier's conservative surgery because many surgeons do not know them or have not understood the bearing of them, which will explain the want of functional success which is wrongly attributed to resection. These surgeons have regarded the preservation of the periosteum as the only point in Ollier's method, and since the osteogenetic power of the periosteum is not always necessary, and as from this point of view it is possible at times to do without it, they have concluded that

its separation is a useless complication, and have returned to their former extra-periosteal (parosteal) methods.

This is an absolute misapprehension of the conservative method, as we shall see.

1. Physiological Incisions.—In 1885 Ollier wrote as follows: "The object is to preserve all the tissues, all the elements essential for the reconstitution of the bones and the joints, while causing the least possible damage to the peripheral organs. To attain this end we must do our operations by methods different from those in ordinary use. One should approach a joint in the same manner as one approaches an artery, namely, through carefully planned incisions. There is no longer any call for rapidity in opening a joint: it should be approached by way of the muscular interspaces without injuring any structure not only important, but merely useful, and without sacrificing any of the requirements of a sound operation, such as room for the operator and space for the movement of his instruments."

These intermuscular incisions are made only in certain well-defined anatomical situations when an arthrotomy or resection is in question. The incision appropriate for each joint, "*the physiological incision,*" is given farther on; it is the incision chosen with due consideration for the future physiological function of the joint.

In war-wounds it may seem impracticable to follow these lines: one will often be tempted to utilise the openings made by the missile. Whenever these are not gaping holes, however, it will be an advantage to approach the joint by the correct route and to utilise the track of the missile, after it has been duly cleaned up, as a route for draining, and not as a means of access. That is a question of dexterity and common sense which cannot be reduced to rules. If it is decided to utilise the existing wound, its walls ought to be

excised with a bistoury so as to transform it into a passage with clean sides without unduly sacrificing healthy muscular tissue. Muscles and tendons ought not to be divided transversely by joining the two openings of a sinus ; in the case of the shoulder particularly, division of the deltoid is disastrous. In a word, a joint ought always to be approached with a full regard to its future movements.

2. Preservation of the Capsulo-periosteal Sheath.—This ought to be preserved, for two reasons : first, to retain the elements essential for regeneration of bone, which is the anatomical aim, so to speak ; second, to maintain intact the factors concerned in the stability and mobility of the joint, the physiological aim.

(*a*) The whole thickness of the periosteum with its deep osteogenetic layer ought to be preserved because, thanks to its activity, the bony extremities are regenerated.

What happens after a resection ?

At each end of the capsulo-periosteal sheath at its periosteal edge, the osteogenetic layer proliferates, thickens, and gives rise to masses of soft consistence and cartilaginous appearance, in which ossification occurs. Two masses of new bone result, which soon constitute new articular extremities between which a new joint is formed.

(*b*) The capsular sheath ought to be preserved because one thus retains inside it a certain number of endothelial cells which favour the creation of a new synovial membrane, and outside it the necessary ligamento-tendinous continuity.

Let us consider first the formation of a new synovial membrane.

At the edge of the capsular portion where the synovial membrane exists, the serous layer thickens under the influence of traumatism ; its endothelial layer sends out cellulo-vascular processes which meet one another

and, blending together, form what will become later the articular cavity.

If the wound does not suppurate, or only does so slightly, we have at hand all the elements necessary for that gliding motion which it is the object of gentle movement to promote during the early stages of the organisation of the wound. Little by little, under the influence of these movements, the endothelial lacunæ enlarge, the partitions wear away and disappear, and finally a new synovial membrane is formed : that is the ideal plan of development.

When, on the contrary, inflammation or operative measures have destroyed these synovial elements, it is much more difficult to form, by means of repeated gliding movements, a sort of hygroma, or an inter-osseous serous bursa, and this is always less perfect and less adapted to its purpose than is the true synovial membrane in the former case. After this explanation it is easy to understand why technique and post-operative care play an essential rôle in the final results of resection if we regard them from the point of view of restoration of function. It is for want of under-standing of this anatomico-physiological development of new joints that some surgeons only get bad results and therefore condemn resection.

If the preservation of the synovial membrane and its regeneration play a large rôle in the post-operative formation of a new joint, it is the preservation of the whole tendino-ligamentous capsule of the joint, and the retention of the muscular insertions in their normal relations to the capsulo-periosteal sheath, which causes the gradual development of the new joint towards the perfect physiological type.

The capsulo-periosteal sheath placed in immediate contact with the bone acts at first like a guardian to the process of osteogenesis ; it limits the new formation of bone, restrains it, and maintains it in good position ; then at the proper time it models it under the action

of the muscles, which, having retained their insertions into the part of the capsule corresponding to the epiphysial tuberosities, remain in their normal position and contract as usual. By their normal action they press on the capsule and make their impress through it on the newly formed bone. In other positions they pull upon and mould the soft bone into shape. In short, their action, which is retained intact by the preservation of the capsular sheath, is constantly tending towards the production of a physiologically normal joint.

The careful separation of the capsular sheath is even more indispensable when the injuries are so extensive that it might seem useless to take all this care. Here, the preservation of the tendinous insertions in the capsulo-periosteal sheath assures the functions of the muscles, permits the secondary drawing together of the widely separated bones, and rearticulates them in some measure ; the capsule then acts as an elongated tendon, and it is by its means that one is able to obtain excellent functional results in many extensive resections.

It is unnecessary to labour this point further.

What are the necessary steps in practice to preserve these indispensable factors for recovery of function ?

After the joint has been opened, as described, and the intermuscular intervals kept apart by retractors, it is necessary first to incise the capsule in the direction of its fibres, or the long axis of the limb. When that is done, the knife is abandoned for the rugine, which should be used throughout the rest of the operation. This rugine should be of a special pattern : for separating the periosteum and its sheath there is only one good one, that of Ollier, with a steel shaft ending in a flattened extremity, as sharp as a razor. This cutting edge is bevelled from its dorsal surface downwards towards the under edge which is kept in contact with the bone (fig. 6).

With this instrument, which has a solid handle, a way is made by degrees between the bone and the periosteum, and one is able to raise the periosteum and the capsule bit by bit, and to preserve intact a fibro-periosteal prolongation of the muscles and tendons. The name "détache-tendon" which Ollier gave to this instrument indicates the object in view. But in order to attain it without accidents, the rugine must be used slowly and forcibly, the right hand being guided by the left index finger applied to the right. With a little practice it is possible to denude the most irregular tuberosities so that finally the bone will be as free as if it had been enucleated from its fibrous sheath. This method is applied to each fragment of bone which is more or less free. Every little fragment, however small, ought to be treated thus; it should be grasped in forceps and its external surface carefully stripped. It is only in this way that the subperiosteal operation can be truly and typically carried out.

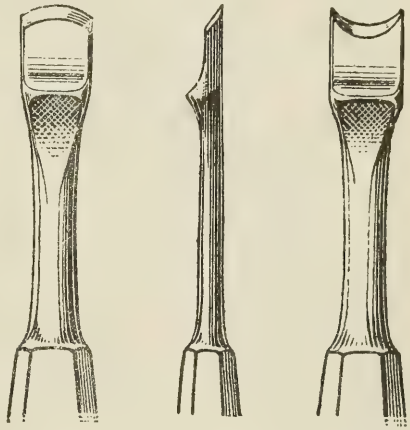


FIG. 6.—Ollier's rugines with cutting edge for the complete detachment of the deep layer of the periosteum, the ligaments, and tendinous insertions.

A final detail will perhaps be useful: as one approaches the shaft, the separation of the periosteum becomes easier. Sometimes a careless movement causes the shaft to project through the separated sheath. This is an accident which is most likely to occur in resection of the elbow when the separation is being carried above the condyles of the humerus, espe-

cially in secondary operations: it can be avoided by care.

3. Division of the Bone.—In resections it is often remarked that it is difficult to steer a correct course and remove enough bone to procure mobility without removing too much to preserve a sufficiently firm joint.

The best sections are those made through the epiphysial ends. It is much more frequently possible to do this than one would think. When these injuries are limited, there is sometimes difficulty in making the bone project sufficiently to divide it, and the surgeon may be tempted to prolong the denudation further towards the shaft: this is useless, and gives very little more room. The difficulty is caused by the periosteal-ligamentous adhesions, and should be overcome by again applying the rugine to each tuberosity, and stripping off these structures transversely instead of axially. A chain saw, or Gigli's saw, can then be used, and the epiphysis divided at a suitable level.

When the injury is more extensive and runs along the shaft, there is no need to conclude that the conservative operation is doomed to fail to restore the function of the joint, and should be rejected. In the majority of these cases the fracture in the shaft runs parallel to the long axis of the bone; a large fragment comprising the articular end and a part of the shaft is detached, but there is no actual solution of continuity of the shaft itself. The pointed end of the latter reaches down to the level of the broken epiphysis, and the saw has only to remove this sharp extremity. If the periosteum has been carefully preserved, bone formation will result, and a new epiphysis will be constituted.

In a number of cases the epiphysis is only fractured on one side; the broken fragment comprises a thin shell of the shaft which is of no importance; enough of the articular end remains on the opposite side for

a unilateral intra-epiphysial section to be made which is sufficient if the periosteum has been preserved.

When both epiphyses are destroyed (*i.e.* T-shaped fracture), it is customary to find fissures extending up the medullary canal of the shaft. Unless resection is performed, these parallel fissures constitute a very

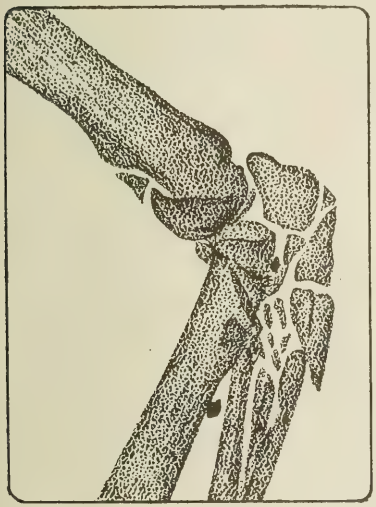


FIG. 7.—Fracture of the elbow by shell-splinters. Total resection of the elbow-joint on the second day, in consequence of the fissured shaft of the ulna.

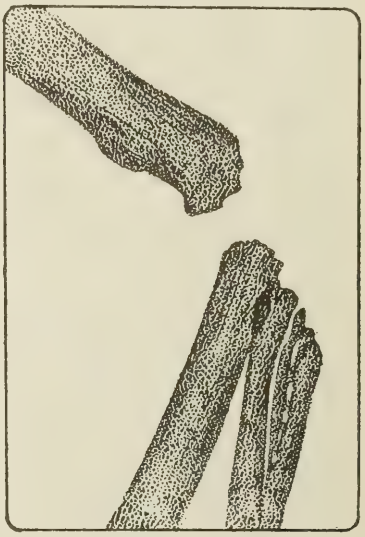


FIG. 8.—The same case as fig. 7. Radiograph fifteen days after resection.

great danger if the bone becomes infected, because it is thus that acute osteomyelitis arises. If, however, the intra-articular fragments are removed, and the wound is systematically cleaned, they frequently weld together and reconstitute the shaft (figs. 7–9). There is no need for anxiety in these cases : the bone section should be performed as if the fissures did not exist.

If the fracture is clearly as much epiphysial as diaphysial, with its centre at the line of junction, it must

be realised that this injury often leads to amputation if resection is not performed at once. But the operation ought to have for its object the preservation of a large portion of the lower fragment of the shaft, which is nearly always possible. The articular end is removed and the limb carefully immobilised in a suitable position for five or six weeks, so that bony union, which is accelerated by the operative measures, may occur in the fractured shaft. Then, but then only, attempts at movement may be made if mobility is desired.

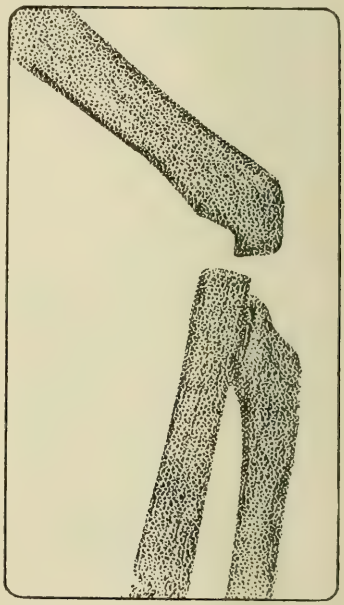


FIG. 9.—The same case as figs. 7 and 8. Radiograph at the end of two months. The wound was healed by the thirty-ninth day; active flexion had then almost reached a right angle. At the end of a year the result is perfect: active flexion and extension are normal; the patient can carry 15 kgs. with the arm raised; pronation and supination are normal.

Thus, resection in certain cases is an operation true to type, in others it consists in removal of all the epiphysial fragments, subperiosteally of course, followed by trimming with the saw.

*When the articular end of one bone only is affected, should resection be confined to that bone?*

This is the usual procedure in certain situations; hemi-resection of the upper end of the humerus is commonly called resection of the shoulder, and femoral hemi-resection resection of the hip. In military surgery, the classical method is adhered to at the hip and shoulder if one bone only is injured, because it is sufficient to ensure good post-

operative results, and because the functional recovery is better when it is so done.

But in other situations it is different. As a general rule, when mobility is desired, it is better to put into contact two bony surfaces, which by friction will adapt themselves to one another, than to oppose bone to cartilage, in which case the adaptation will not be so good, since the unmouldable cartilage will remain as it is, the other surface having to do all the work of fashioning the joint. At the elbow this is very clear: no doubt some perfect results are obtained from hemi-resection, but more often the articular movement becomes checked at a certain stage; in the lower hemi-resections of the elbow (*i.e.* of the bones of the forearm) the movement of active flexion beyond a right angle can only be effected after a sudden slide over the anterior trochlear surface. In the superior hemi-resections (*i.e.* of the humerus) one never restores pronation and supination. At the elbow, then, it is better to do a total resection, unless the loss of substance in one of the two bones is too great. In the resections where ankylosis is aimed at, as at the knee, there is great advantage in bringing two bleeding bony surfaces into apposition. It is illogical to allow contact between bone and cartilage if one wishes to obtain firm bony union; and besides, the removal of a thin slice of cartilage does not add greatly to the loss of substance. Thus, except at the hip and shoulder, a resection of both articular ends should be the rule.

4. Drainage.—The best method of draining a joint which has not been resected is to insert drainage tubes into small openings in the capsule. It is better not to pass them in deep, and not to insert any transversely, aseptic though they be, across a serous membrane which does not tolerate them well. In the case of the pleura, this rule is well established; in the case of the synovial membrane it holds equally well.

When the case is one of resection instead of an arthrotomy, the injuries being largely exposed, I do not as a rule put in drainage tubes, but insert tampons of aseptic gauze gently without force or pressure. Gauze is regarded as holding up the discharges, and many surgeons proscribe it for that reason. It is probable that they plug too forcibly, which makes it ineffective, or that they leave the dressings in place too long. These are questions of personal practice which are not absolute rules. The principal point is to leave the wound wide open without suturing it, as A. Poncet always advised in all surgical casualties.

5. Immobilisation.—Every joint that has undergone injury or has been operated upon ought to be immobilised. In principle, the only good immobilisation is that which fixes the joint above and that below, as A. Bonnet advised, and the realisation of this ideal ought to be striven for. After resection, however, it is not absolutely necessary everywhere ; thus in the case of the elbow it is useless to immobilise the shoulder ; but as a general rule the principle holds.

The best immobilising agent is the plaster casing. I think that at first this method should always be used (except at the elbow, where I often omit it). Metal splints ought only to be used if there is no time to make others. It is only later on that the wire splints or plaster-of-paris splints with windows are indicated. The former do not immobilise as well as the plaster casings, the latter make it difficult to inspect the limb ; Ollier abandoned them twenty-five years ago. In spite of their present vogue they should only be used sparingly for joint injuries, and even then always only temporarily.

6. Dressings and Sunlight Therapy.—After primary resection performed early, the course of the wound is uniformly aseptic. Dressings can and ought to be done seldom ; the post-operative dressing may well remain unchanged for 8 to 15 days. In

all cases one can and ought to dress the cases only occasionally unless sunlight treatment is possible.

After secondary (*intra-febrile*) resections, it is often necessary to do the first dressing as early as the end of 2 to 4 days, but after this has been done it will be advantageous to disturb the wound as seldom as possible. I have seen intra-febrile operations for the removal of the astragalus healed in 60 days after 6 dressings, some secondary resections of the elbow in 39 and 45 days with 2 dressings between the 1st and 15th days, after which the necessity of movements called for greater frequency. The current fashion then is few dressings, and, I would like to add, not voluminous ones. There is a tendency to use too much wool, to bury under enormous layers a wound which wants to be aerated, a skin which is best exposed to the air and the sun. A custom which is very expensive and particularly bad is to envelop the limb in non-absorbent wool sterilised or not.

These bad practices ought to be abandoned.

In general it is well to do the first dressing under ethyl-chloride anæsthesia; one is able thus to remove the gauze and replace it without pain. After each dressing strict immobilisation is renewed.

If the climatic conditions allow of a sun bath, the procedure is different: insolation and a change of dressing will be the daily rule. In these circumstances a very light dressing is employed. Those who have never practised heliotherapy can have no idea of the truly magical effect of the sun on surface wounds; in a few minutes, under one's eyes, the bleeding surface is entirely modified. A sitting of a quarter of an hour suffices to get rid of the sloughs and after three or four sittings suppuration is at an end. This result is due to a regular flow which occurs from within outwards. If the sun is rather strong, at the end of five minutes on an average one sees the wound dotted with red spots; at the end of seven minutes

a sort of pink serum exudes having the appearance of blood serum; the flow is abundant enough for one easily to collect an appreciable quantity if one wishes. Then the wound becomes glazed; it takes on a fine reddish tint, and if touched it bleeds. In short it gives the impression that some embryonic capillaries are formed on the spot in a few moments, and that the wound is vascularised as if by some intense reaction.

At the end of some days the wound is considerably reduced in size; cicatrisation progresses with wonderful rapidity, and healing is obtained more quickly than by any other method. But insolation has yet another advantage: under its action the muscles do not atrophy but they remain strong and vigorous. When it is desired to re-establish movement in the joint the period of passive movements is much shortened; the power of active contraction is recovered in a few days. I have seen patients whose elbows have been resected move their forearms themselves fifteen days after operation. One patient at the end of forty days was able to lift $1\frac{1}{2}$ kilogrammes with arm extended, and then to raise it beyond a right angle. Heliotherapy is an expedient no one should overlook.

7. Mobilisation.—If one does not deliberately seek for ankylosis, whether after arthrotomy or resection, early movement is the condition necessary for the recovery of the functional power. But this ought not to be begun until the day after all pain has disappeared; it should only be continued if the passive movements can be performed without any acute pain and without producing inflammation. There are no other rules than these. It should never be forgotten that absolute rest and immobility form the basis of all treatment of inflammation. By not obeying this law one runs counter to the end in view.

On the other hand, if the period of immobility is

unnecessarily prolonged, the formation of bony ankylosis and firm ligamentous adhesions is favoured. It also induces a muscular atrophy that is often irremediable. It is not well, then, to prolong the period of joint-rest too far. But attempts at movement must be made very gently ; any undue force is paid for by inflammation which increases the tendency to ankylosis. In fine, if recovery of the normal function of a joint is sought for after an operation, one must avoid three dangers : too prolonged immobilisation, too rapid mobilisation, and forcible mobilisation. Neglect of this is the explanation of many failures.

Mobilisation, therefore, should be begun very gently but early, subject to the above reservations (no pain, no temperature, no secondary reaction), even if there is much loss of bone. In this case the muscles have got to take the place of ligaments in the new joint : it is essential to preserve them to the utmost. But in the intervals between the short trials of passive movement there must be complete immobility with the bones in contact.

Care is necessary not to exceed the limit : so persuaded does one become of the necessity of movements that one is apt to consider the patient who does not wish them to be performed as cowardly or hypersensitive. Either they are imposed upon him as a stern necessity, or they are done unexpectedly, which is the worst of methods. I have often witnessed the deplorable results of too much zeal. As Ollier has written, " If docility on the part of the patient should be his greatest virtue, patience on the part of the surgeon is no less necessary. It is a mistake to hope to obtain in eight days what requires several months. It is not a matter of conquering resistance and of breaking down adhesions, but of favouring the reconstitution of gliding movement and the regeneration of an interposed serous membrane. Time is indispensable for these things. Too violent or too pro-

longed exercise is capable of injuring the tissues which it is intended to make supple, and of inducing a plastic and adhesive process instead of creating a sliding joint."

By adopting these precepts one is sure not to end either with ankylosis or with a flail-joint. The latter, with its complete loss of power of active movement, is primarily due to complete muscular insufficiency and bad post-operative management. When a primary resection has been done, the muscles are vigorous and strong, nothing has atrophied them; when they contract, they press the articular surfaces closely together; they articulate the new joint and permit to it a play of movement of satisfactory amplitude and precision, even if the resection has been very extensive. Doubtless in war-wounds one should not look for the ideal anatomical result of the resections performed in peace-time with their perfect restoration of the bony extremities in their normal position bound together by a marvellously regular ligamentous apparatus; but the important point is to obtain a satisfactory physiological type. Only great patience is capable of producing this result with certainty. Speaking generally—I might almost say, speaking literally—mechanical therapy ought to be proscribed: it has often led to disaster, from not taking sufficient account of resistance and of pain; it is too brutal, however gentle it may be, and tries to go too fast. Many resections of the elbow have ended in ankylosis because it has been imagined that a new joint could be produced by a mechanical machine.

8. Later Appliances.—Some patients after recovery from arthrotomy or resection derive advantage from wearing a simple supporting apparatus for some months: for the elbow or the wrist a bracelet or gauntlet of leather, for the knee a laced splint, for the foot a boot with lateral supports. After resection of the knee a leather splint with rigid supports should

be advised during the first year or two. After resection of the hip a raised boot is necessary, an orthopædic apparatus useless.

9. Evacuation of Patients with Wounds of Joints.—As far as can be, wounds of the joints should be treated on the spot, moved as little as possible and evacuated as late as can be managed. In a war of position every joint wound, however small, ought to be operated upon immediately after the patient has been brought in, for it is only in this way that a small wound can be made to remain harmless. The patient's evacuation after operation should be carried out after complete immobilisation has been effected: the apparatus to be preferred is a plaster trough. But evacuation ought not to be ordered, save for military necessity, except for convalescents, that is for patients who have been free from fever for many days, who have no pain, and whose wounds are clinically aseptic.

## CHAPTER I (Continued)

## GENERAL SURVEY OF PRESENT METHODS FOR OBTAINING WOUND ASEPSIS

The presentation of modern methods of treatment for infected wounds meets with difficulties at this particular time. Opinions are still divided concerning the value of certain new procedures, notably the Carrel-Dakin treatment by multiple irrigation of war wounds with a special antiseptic fluid; a method which has won popular favor and has been accepted by the United States Government for its military medical services. Prominent German war surgeons, such as V. Bruns and others, are equally convinced of its superiority, and on the basis of extensive experience with this treatment in the worst type of artillery and similar injuries are inclined to regard sodium hypochlorite as the turning-point in the treatment of infected war wounds and the hoped-for solution of the problem of chemical wound-disinfection.

The status of the treatment of war wounds as it existed at the inception of the war eventuated in the speedy revelation of the inadequacy of the procedure then in use. The failure of antiseptics and asepsis as practised in the early days of the war has since been shown to be due, not to a fallacy of the fundamental principle, but to the inadequacy and incompetence of the older technics and disinfectants to deal with the new type of artillery wounds and the intense contamination of the soil of the battle fields with a multiple of anaërobic germs. From the failure of the old grew the involution of modern methods of wound treatment. A conflict arose between the antiseptic or Listerian methods, essentially represented by the Carrel-Dakin wound

treatment, and the purely physiological method of Sir Almroth Wright and his school. The gradual improvement of the antiseptic methods is represented by the evolution of the chlorine compounds, with the work of Dakin, Lorrain Smith, Geo. Makins, J. E. Sweet, and others. The drawbacks of the hypochlorites, the hypochlorous acid preparations, and the hypertonic salt solutions led to the elaboration of Dichloramin-T and its substitutes, to the introduction of Flavine and Bipp, to Delbet's method of hypoculture and his magnesium chloride, to the use of Vincent's powder, Hey's brilliant green paste, and a number of other methods of wound treatment. Special mention must be made of the new Serotherapy introduced into wound treatment, notably in form of the polyvalent serum of Leclorinche and Vallee, the merits of which are not yet sufficiently appreciated, for lack of familiarity with the results accomplished.

The success of all modern methods of wound treatment is based upon the fundamental principle of complete mechanical or surgical sterilization, the excision of all dead or dying tissue, the extirpation of whole wounds and bullet-tracts, which admits of even immediate suture of war wounds in selected cases. It goes without saying that only the most highly skilled and experienced surgeons are qualified to carry out the primary closure of war wounds. Primary suture of wounds, as practised by prominent French pioneers in this field, after excision and during the period of contamination, in other words, prophylactic excision of the contaminated wound tissue, although not yet generally accepted, is practically the last word in war surgery. It is this greater attention to the mechanical or surgical sterilization of wounds which has made the striking difference in the results obtained now and at the beginning of the war. The success which has lately attended the treatment of infected war wounds on the Western front, as contrasted with the acknowledged

failure of surgery in the first year of the war, is undoubtedly due, not so much to any one of the numerous antiseptics now in vogue, but to the thoroughness with which the contaminated areas are extirpated surgically during the period of contamination, in the first ten or twelve, at most fifteen hours, before actual infection has taken place. The extirpation of the dead or hopelessly damaged tissue, before the germs have had time to incubate, is the secret of success, and it is for this reason that nearly all methods of chemical sterilization yield good results. Future investigators may be expected to throw light on the individual characteristics of the infecting bacteria in war wounds, and the specificity of antiseptics employed for the control of these infections, a line of study suggested in the Archives de Med. et de Pharm. Militaire of 1917. The disinfection of war wounds is the easier the earlier it is begun; in other words, the closer the treatment follows the production of the wound. Surgical prophylaxis of infection is the fundamental feature of the present treatment of war wounds, its progress, and success.

The principles of modern methods of wound treatment differ so radically and intrinsically as hardly to admit a classification of therapeutic procedures now in use under the heading of antiseptic, physiological, vaccine, and other methods. Any attempt at such grouping would necessarily be open to criticism, as not uncommonly these methods are combined or overlap. A diagnostic-therapeutic procedure such as Delbet's pyoculture method requires a place by itself, and this is also true to a certain extent for a few other curative suggestions which have been offered. Although some logical sequence has been aimed at in the arrangement, the different methods are described independently, and irrespectively of kindred, competitive, or opposite ideas on the management of infected wounds. It is not the object of this book to extol any of the curative

procedures which have been called forth in abundance by the wholesale slaughter on European battle fields, nor is it proposed to enter into a discussion of the value of these methods from the scientific viewpoint of surgical pathology. Without criticizing or grading the various methods, the fact is emphasized that all very recent methods of wound treatment are of necessity more or less experimental and under trial. The text aims at presenting in concise but intelligible form the modern methods of wound treatment now in use, so that they can be tried and tested by those interested in their practical utility.

The aseptic effectiveness of the first wound dressings, as pointed out by Vincent, often governs the surgical prognosis. After the wound has been virtually made clean and free from necrotic matter a successful course of repair and a favorable outcome are assisted and ensured by the purposeful selection and proper utilization of the most advantageous chemical agent. An article is intended to help the reader not only in this choice, but also to provide him with sufficient grounds on which to base his own judgment as to the relative merits of modern methods of wound treatment.

## The Carrel-Dakin Method

The novelty of the Carrel method of wound treatment consists in its providing a protracted and intimate contact between a relatively non-irritant antiseptic agent and the infected wound surface. In pursuance of this object the same degree of concentration of the antiseptic solution must be constaintly maintained, and this necessitates a special technic for the constant renewal of Dakin's fluid, which is very unstable and easily decomposed.

A preliminary requirement of this as well as all other modern methods of wound treatment is the earliest possible and scrupulously careful cleansing of the in-

fected wound, preferably within the first six hours, with free incisions, removal of all foreign bodies, and extirpation of all hopelessly damaged or dead tissues. This surgical cleansing of the wound is followed by the institution of the Carrel procedure, which has for its main object the sterilization of the wound by chemical means, and aims at accomplishing this purpose through a special mode of application of a definite antiseptic solution, i.e., Dakin's fluid, claimed to be approximately isotonic with blood serum. The early union of the wound margins by sutures or other means which this method renders practicable is the best proof of its efficiency in the treatment of infected war wounds. The results of the Carrel method in badly infected artillery and similar wounds are described as far surpassing those obtained by other methods. The temperature drops to normal within 48 hours; after a week's treatment, the appearance of the wound surfaces is very favorable; the entire duration of the treatment is considerably shortened in comparison with other methods. This wound disinfection guards against lymphangitis and lymphadinitis, as well as against osteomyelitis in infected compound fractures; amputations are rarely needed, in spite of the gravity of the cases, and deaths from sepsis are exceptional. The cicatrices following the junction of the disinfected and sterilized wound surfaces resemble operation scars rather than those obtained by the secondary suture of granulating wounds. This outcome constitutes a valuable auxiliary in the mechanical after-treatment of war wounds.

A special committee appointed by the Director-General of the British Army Medical Services for the purpose of investigating and reporting on the Carrel-Dakin treatment of wounds is of the opinion that this method of treatment, if carried out thoroughly, is full of promise, and believes that it will (1) diminish the dangers incidental to sepsis, including secondary hemorrhage; (2) hasten the patient's convalescence; (3)

lessen the liability to stiff joints and cicatrical deformities; (4) enable the patients to leave the hospital with better general health than they otherwise might; and that (5) when secondary operations become necessary these operations are more likely to be free from septic complications than when some other system of primary treatment has been adopted. (Brit. Med. Jrl., II, 1917. p. 597.) In conformity with these views, the British Army Medical Department has arranged that the treatment can be continuously carried out not only in the Front and Base Hospitals but also in ambulance trains, hospital ships, and the hospitals in Great Britain. (Sir Anthony Bowlby.)

The method takes its name from the technic specially devised by Alexis Carrel for bringing Dakin's fluid of sodium hypochlorite into contact with the interior of infected wounds. Dakin's solution in a septic wound acts both as an antiseptic and as a cleansing agent or remover of dead tissue liable to serve as a nidus for microörganisms. Although it slightly irritates the skin, this disinfecting fluid does not injure living tissue, and it is described by Dr. Lyle as an ideal isotonic wound antiseptic of high bactericidal and low toxic or irritating quality. The solution possesses hemolytic properties and will dissolve recent bloodclots; so that a good hemostasis is essential to guard against the dangers of secondary hemorrhage.

In order to combine the strongest germicidal with the lowest irritating action, the solution must be of definite strength, namely, between 0.45 and 0.50 per cent. The fluid is deprived of its chlorin in an hour or less by the wound secretions, which render it inert. The many details of the necessary technic require the attention of a large, well-trained staff of doctors and nurses, so that the method is hardly applicable outside of a thoroughly equipped modern hospital. Several modifications and simplified apparatus have been suggested and will receive consideration in the text.

Dakin's fluid is used in a solution of 0.5 per cent. strength, and is prepared according to two formulas, with and without the addition of boric acid. Practical experience with the two solutions apparently favors the boric acid free fluid. The following formulas for the preparation of the two fluids were given by Dr. Dakin.

### Dakin Solution Without Boric Acid

"Neutral hypochlorite prepared without boric acid is best made according to the formula given by Daufresne, and at the present time is perhaps more generally used than any of the other modifications. Two hundred grams of good bleaching powder are put in a 12-liter bottle with five liters of tap-water. The solution is shaken vigorously and allowed to stand for at least six hours, unless a mechanical shaker is used, when half an hour's shaking will be found sufficient. In another vessel, 100 grams of dry sodium carbonate and 80 grams of sodium bicarbonate are dissolved in five liters of cold water and then added to the bleaching powder mixture. The whole is shaken vigorously for a few minutes, and the precipitate allowed to settle. At the end of half an hour the clear solution is siphoned out and then filtered through paper. The proportions given above for the carbonate and bicarbonate of soda are those given by Daufresne. It is our experience, however, that with most brands of American bleaching powder it is better to use 90 grams of each salt. This solution must invariably be tested for neutrality by adding a pinch of solid phenolphthalein to a little of the solution. If the solution should react alkaline, one of three methods must be employed to correct it, otherwise skin irritation will surely result.

"(*a*) Pass carbon dioxid gas into the solution until a sample shows no alkalinity when tested as described. This is perhaps the best method.

"(*b*) A neutral hypochlorite may be secured by re-

ducing the proportion of carbonate of soda and increasing the bicarbonate.

"(*c*) Boric acid may be added until neutrality is secured. An advantage of the carbonate preparation is that it possesses greater stability and can be kept for several weeks without much deterioration. On the other hand, with varying qualities of bleaching powder, containing different amounts of free lime, it is more difficult to adjust the proportions so as to obtain a neutral solution directly. Probably those having adequate laboratory facilities will prefer the carbonate-bicarbonate solution, while the mixture containing boric acid is readily made under less favorable circumstances."

### Dakin Solution with Boric Acid

"Neutral hypochlorite prepared with boric acid is best made as follows: One hundred and forty grams of dry sodium carbonate ($NaCO$), or four hundred grams of the crystallized salt (washing soda) are dissolved in twelve liters of tap-water, and two hundred grams of chloride of lime (chlorinated lime) of good quality are added. The mixture is well shaken, and after half an hour the clear liquid is siphoned off from the precipitate of calcium carbonate and filtered through a plug of cotton; forty grams of boric acid are added to the clear filtrate, and the resulting solution is ready for use. A slight additional precipitate of calcium salts may slowly occur, but it is of no significance. The solution should not be kept longer than one week. The boric acid must not be added to the mixture before filtering, but afterward. The solution should be tested by adding some of it to a pinch of solid phenolphthalein. If a red color, indicating free alkali, should develop, a little more boric acid must be added in order to remove it."

No caustic alkali must exist in sodium hypochlorite solutions destined for surgical use.

A very simple and practical test for alkalinity is recommended by Dr. H. H. M. Lyle:

Pour 20 c.c. of the solution into a glass, and drop on the surface of the liquid a few centigrams of powdered phenolphthalein. Agitate the fluid by giving the glass a circular motion, as if one were rinsing the glass. The liquid ought to remain colorless. A red tint more or less intense indicates the presence of a quantity of free alkali, or an incomplete carbonation due to faults of the technic.

### Titration of the Solution (Lyle)

"Measure 10 c.c of the solution, add 20 c.c. of 1:10 iodin solution and 20 c.c. of acetic acid. Pour into this mixture a decinormal solution (2.48 per cent.) of sodium thiosulphate (hyposulphite) until decoloration. Let N equal the number of cubic centimeters of thiosulphate employed. Then the quantity of sodium hypochlorite for 100 c.c. of the solution would be given by the equation:

$$T = N \times 0.03725.$$

"Precautions: Never heat the solution. If, in case of an emergency, it is necessary to titrate the chlorinated lime, use only water, never with the solution of soda salts.

"*Do not use old solutions.* Hypochlorite solutions change quality in the light, more slowly in the dark, but will not keep indefinitely under any conditions. For practical purposes, sodium hypochlorite, when properly kept in a dark place, does not lose in strength as regards its effectiveness (the deterioration not exceeding 0.505 to 0.500 in three weeks)."

### Equipment

(1) A sodium hypochlorite solution of 0.5 per cent. strength, prepared according to the technic described above.

(2) A glass receptacle holding from 500 to 1000 c.c.

(3) Ordinary medium-sized rubber tubing, two yards.

(4) A movable clamp for the regulation of the flow through the main distributing tube.

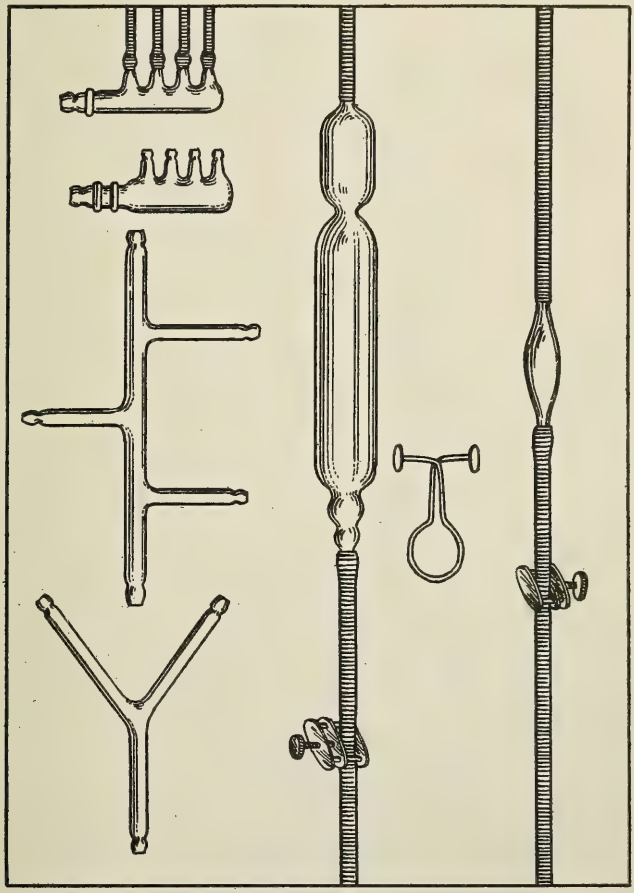


Fig. 1a.—Glass Connection Tubes, Vision Tubes and Stop-cocks.

(5) Rubber instillation tubes of assorted widths (average size No. 16 French) and about 25 cm. in length. The ends are tied, and a number of very small

holes are then punched out of the tubes; these holes are no larger than 1 mm. or 1/25 of an inch in diameter. The internal diameter of the primary and second-

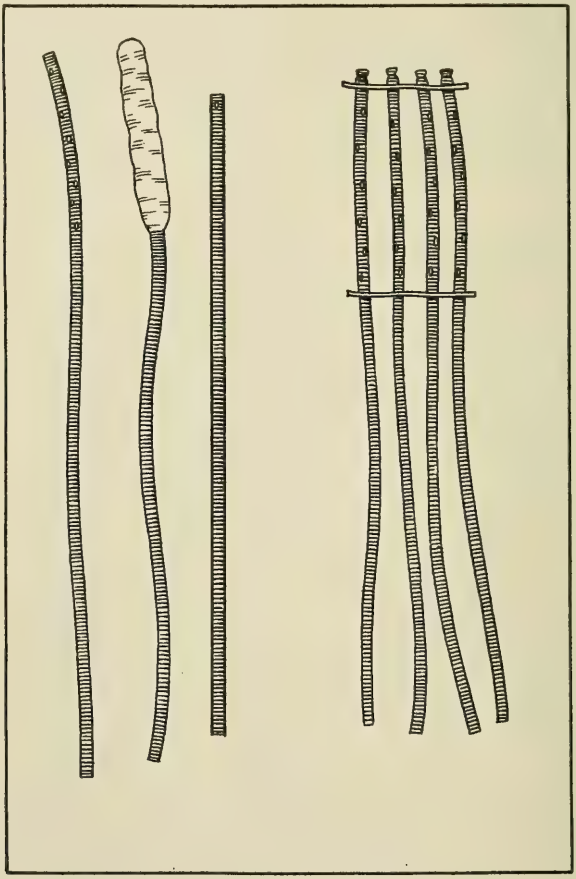


Fig. 2a.—Carrel's Distributing Tubes.

ary tubes is 7 mm. and that of the final distributing tubes is 4 mm.

(6) Ordinary rubber drainage tubes, without perforations, 25.35 cm. in length.

(7) Glass tubes for connection and distribution.

(8) Cotton surrounded by gauze, for dressings of different sizes, (1) fitting well around the leg; (2) fitting well around the arm; (3) a small size. The thickness of these dressings is about 3 cm.; they consist of a layer of absorbent cotton and a thicker layer of non-absorbent cotton. The dressing is held by straps of webbing, with adjustable buckles.

(9) Sterilized gauze squares soaked in yellow vaselin (petrolatum) serve for the protection of the skin. White vaselin must not be used.

### Employment of Hypochlorite Solutions

(1) Preparation of the Wound.—The first surgical intervention—which should be as prompt, thorough, and aseptic as possible—comprises a routine mechanical wound disinfection, with removal of all foreign bodies, fragments of projectiles, shreds of clothing, and so forth. The following rules have been laid down on the basis of practical experience: Paint the part with iodine tincture, and trim away the necrotic skin edges of the wound with a sharp knife. Lay the wound open, using clean instruments, and remove all that does not belong there or that may have been infected, giving special attention to all pouches and wound recesses, as possible lurking-places of a latent infection. Be gentle and conservative, sparing all non-infected tissues and all those reasonably safe from infection.

Save all that can possibly be saved of comminuted bone-fragments.

The patch taken by the projectile must be carefully resected and the exposed muscular surfaces be freed from adherent dirt and other contamination. Bone wounds require the same accurate mechanical cleaning as soft parts wounds. Finally, the wound must be carefully examined from the standpoint of a reliable hemostasis. Not only is it difficult to disinfect blood-infiltrated muscle tissues, but recently formed blood-

clots are liable to be dissolved by hypochlorite solutions, involving the danger of secondary hemorrhage.

The object of the hypochlorite technic is to keep the disinfecting liquid in constant contact with all the surfaces of the wound. Counter-openings for dressings are only exceptionally applied, and when needed must not be placed at the most dependent point.

(2) Introduction of the Instillation Tubes.—The nature of the wound governs the placing of the tubes, which must be put so as to bring the disinfecting fluid into direct contact with every portion of the wound. The technic varies according to the superficial, penetrating, or perforating character of the lesion.

(*a*) *Surface Wounds.*—These wounds are covered with a thin layer of gauze, on which lie the instillation tubes, in a number adapted to the needs of a given case. Rubber cuffs and sutures retain the tubes at the wound

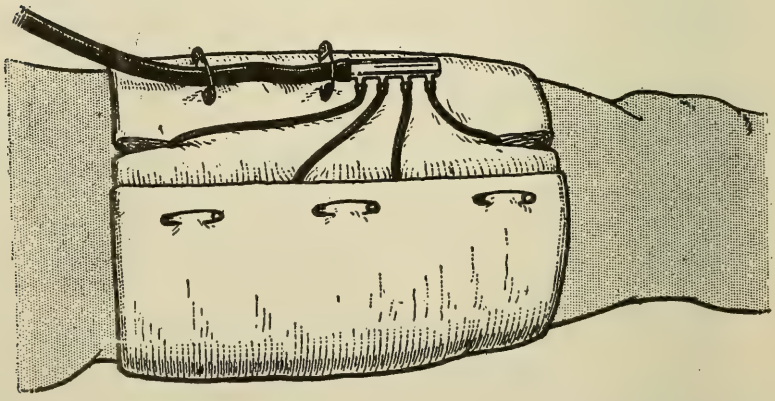


Fig. 3a.—Showing the mode in which the small distributing tubes are carried through the dressing to the various parts of the wound (Carrel and Dehelly).

margins. A two-way flax tube is sometimes used. The placing of the tubes directly on the surface, without the intervening layer of gauze, would result in clogging

and blocking of the orifices by granulations. Access of the germicidal solution to all parts of the wound would be hindered by thick gauze layers stiffened with the secretions of the wound.

(*b*) *Penetrating Wounds.*—One readily understands how a rubber tube without openings in its walls is passed down nearly to but without reaching the floor of a simple wound cavity, with the result that the disinfecting liquid wells up from the bottom. The ragged walls of wound cavities at the end of wide channels must be held up by means of a little gauze, so as to facilitate the universal spreading of the bactericide. Perforated tubes wrapped in toweling (see Fig. 2a) are used for penetrating wounds with a low dependent point of entrance (posterior surface of legs and arms, back, and buttocks), but non-perforated tubes may be employed, the essential point being the continued contact of the disinfecting agent with the wound.

(*c*) *Perforating Wounds.*—Infection of such wounds is controlled by passing a perforated tube, tied at its end, from the lower to the higher wound. The disinfecting liquid is distributed over the entire wound as it flows from the small openings in the tube and returns to the lower orifice along the wound channel.

A hypochlorite bath of ten to fifteen minutes is the treatment for open amputation stumps and for peripheral wounds of the extremities, to be repeated every two hours until the wound is sterilized. Cutaneous irritation with the soda hypochlorite is guarded against by smearing the skin with sterile yellow vaselin.

Technical Precautions.—In order to secure sufficient penetration of the disinfecting fluid, it is imperative to guard against certain sources of error, as follows: (1) Slipping or dropping of one of the conducting tubes. (2) Blocking of one or more tubes by bloodclot. (3) Kinks and bends in imperfectly placed tubes. (4) Neglected wound recesses, not reached by any tube.

The irrigation apparatus is sometimes incorrectly installed, a common fault being that a drop-counting appliance is connected with a number of tubes; here the

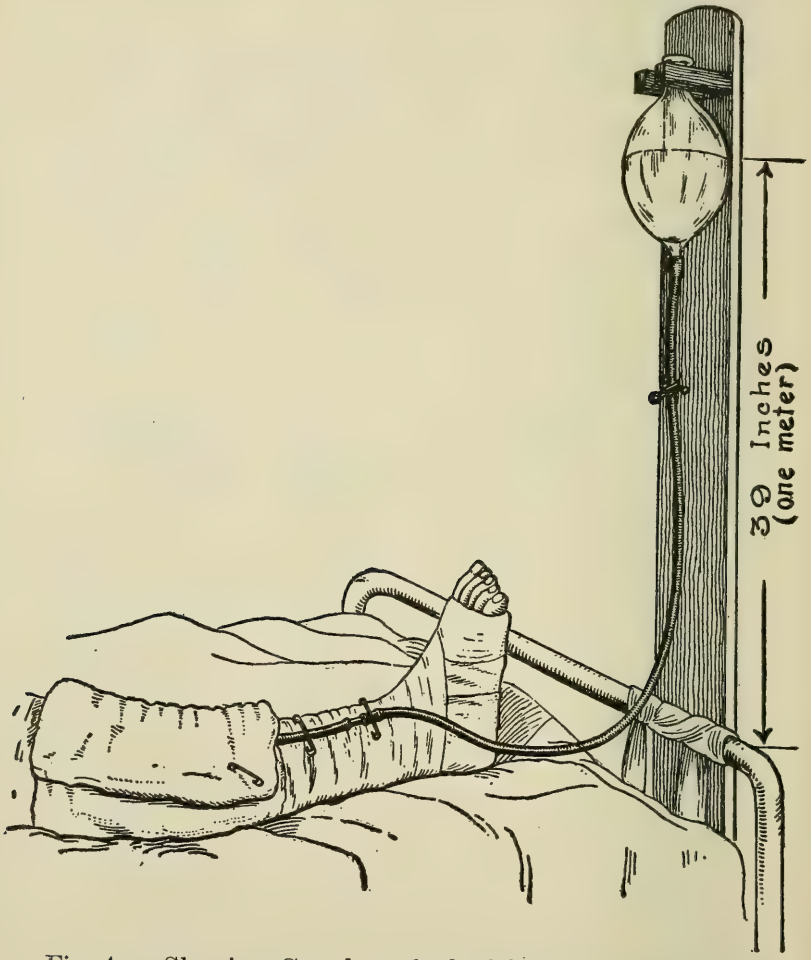



Fig. 4a.—Showing Carrel method of irrigating wound with the Dakin Fluid. Note on the main distributing tube the pinch-cock below the reservoir. The wound is covered with the dressing, which is fastened by safety-pins. The distributing tube is similarly held in place by being pinned to the plaster cast (Carrel and Dehelly modified).

fluid may flow down one tube to the exclusion of the others, in conformity with the laws of gravity. A very narrow main tube, or a very small inferior outlet of the reservoir, will reduce the flow, so that the bactericidal fluid does not pass along as many tubes as it should in order to disinfect the entire wound. Rules concerning the relative calibers of the several tubes and the installation of the irrigation apparatus must be strictly followed.

An insufficient delivery of disinfecting fluid is a more serious error than an excessive amount, which is troublesome to the patient, but will not harm the wound itself, as will an inadequate supply of hypochlorite. This is indicated by the presence of unmodified secretions in the wound and an offensive odor of the pus.

Fig. 5a.—Nurse using a pinch-cock and so instilling antiseptic liquid.

Pain is caused by excessive pressure of liquid in the wound, which is sometimes due to a very small incision retarding the back flow of the fluid between the walls of the wound and the conducting tube. Another easily remedied occasional cause of excessive pressure is the exaggerated elevation of the reservoir above the level of the bed.

*The Healing Wound.*—Only sterilized instruments, never the gloved hands, are allowed to touch the wound or the dressings. Once in two hours, or twelve times in the twenty-four hours, the disinfecting fluid, usually to an amount of 10 c.c., and at a rate of flow of from five to twenty drops per minute, is passed into the wound. This is accomplished by releasing for a few seconds the pinch-cock which regulates the flow, and requires the attention of a nurse. The instillations are continued until sterility has been obtained, as shown by the routine bacteriological control. The instillation tubes are then replaced by a compress soaked in the hypochlorite solution. The progress of the wound and the condition of the irrigation apparatus are ascertained by frequent inspection, at least once daily.

Bacteriologic Control of the Wound.—Determining the number of bacteria on the wound surface is an integral item in the Dakin-Carrel method. The diminishing quantity of germs is the indicator of advancing sterilization. The progress of the wound is ascertained by means of "smear specimens," which are easily interpreted by those having even an elementary knowledge of bacteriology. Cultures are less desirable for this particular purpose, the object being to find out what the wound actually contains rather than what growths might be obtained in the incubator. No smears can be prepared from a bleeding wound, as the blood will effectually conceal the bacteria.

*Technique.*—A stiff platinum wire, mounted on a glass rod, serves for the removal of the specimen from the wound. The standard loop in use in bacteriological

laboratories answers the requirements. The material must be taken at the end of the two hours' interval between treatments, and from the deeper regions most likely to be contaminated, such as jagged wound recesses, damaged bony surfaces, necrotic fascia, etc. The loop transfers the material to microscopic slides, with identification labels. The slides are then taken to the laboratory, where they are fixed and stained.

*Fixation and staining of specimen.*—Pass the slide, smear towards flame, three times through the flame of a Bunsen burner. Next, place it on a glass support and cover with a few drops of carbolized thiolin. Let the stain act for half a minute, then wash with water, and put aside to dry.

*Counting of Bacteria.*—Place a drop of cedar oil on each slide, and count the number of germs in a microscopic field with a No. 12 immersion objective and a No. 3 eye piece. It is advisable to examine several fields, especially near the end of the treatment, before a wound is closed. Only a rough estimate of the number of germs in a microscopic field is required, the object being to ascertain the progress of the treatment. The control is made every day, and the findings are noted on a chart. Absence of germs indicate a sterile wound, which may be closed by sutures. Not less than three successive sterile counts should be relied on.

After the hypochlorite treatment is stopped, a sterilized wound may be re-infected by way of the epithelial margins and the adjacent skin. To guard against this re-infection, it is recommended to wash the entire surroundings with neutral oleate of soda.

The hypochlorite treatment sterilizes soft parts wounds in five to nine days, as a rule. Contused wounds with extensive tissue destruction need a more prolonged contact with the disinfecting fluid. From two to four weeks are required for the sterilization of fractures; all bone sequestra must be removed. Germs persist the longest on the skin and bony surfaces.

Microörganisms without distinction of species are destroyed by hypochlorite; but although the free anatomical elements are equally affected, the defensive

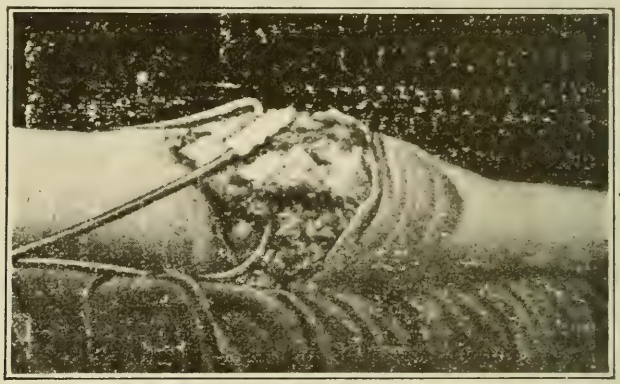


Fig. 6a.—Case 577. Wound of knee, 5th day

phagocytosis, according to Carrel and Dehelly, is not disturbed in the deeper regions unreached by the solution.

*Closure of Wound.*—A wound shown to be sterile by three successive bacteriological tests is ready for closure; usually after a week to nine days, on the fifth day in favorable cases. Layer sutures are the preferred mode of closure. When the suture method is not applicable, elastic adhesive straps are used to draw the wound edges together. The straps must be long enough to be passed around the entire circumference of the limb, guarding against too tight a compression by a circular bandage.

Elastic traction is utilized to overcome an extensive loss of substance, which prevents the apposition of the wound margins. Strips of adhesive plaster about three inches in width and four inches longer than the wound are punched on one edge and shoe-hooks are inserted at intervals of two cm. Two such strips are attached to the skin parallel with and on each side of the wound.

Strong rubber laces are passed over opposite hooks, and by virtue of their elasticity progressively bring the wound margins together. The hooks can also be in-

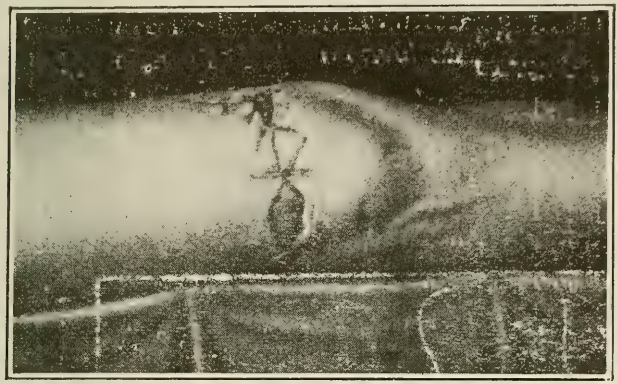


Fig. 7a.—Case 577. Suture, 14th day

serted into the hemmed edges of two canton flannel bands, slightly longer than the wound, and a trifle narrower than half the circumference of the limb. The woolly side of the flannel is placed on the skin, which has first been painted with resin varnish, or Heusner's glue, up to the edges of the wound. The rubber lacing is carried out as with the strips of adhesive plaster.

*Operative Technique of Carrel-Dakin's-Daufresne Treatment.*—According to Captain R. M. Rowe, of the British Expeditionary Force: "Whenever possible, the wound should be converted into a broad-based crater and all damaged tissue detritus and free fragments of bones removed. Hemostasis is most important, by ligature, pressure and hot water. It is a faulty technic to introduce the irrigation tubes into an oozing wound. The tubes must be inserted first into the depths and recesses, then more superficially. The tubes are made stable by fragments of one-inch web bandage removed from Dakin-Daufresne solution and arranged lightly in contact with the distal extremities of the irrigation

tubes. The irrigation tubes (4 mm. calibre and 30 cm. long) are tied at the distal end with linen thread. Perforations extend from this point for 5 cm., 10 cm. or 15 cm. along the length of the tube, so as to vary with the dimensions of the wound treated." (Brit. Med. Jrl., II, 1917, p. 389.)

In order to obviate the necessity for a trained hospital staff, as required by the Carrel method, several types of simplified irrigation apparatus have been devised, which aim at carrying into the wound, at stated intervals, an amount of liquid which can be arbitrarily regulated.

The following change in the Carrel method of irrigating wounds is suggested by Kellock (Lancet, II, 1917, p. 348), who found it of much service: "Taking a piece of drainage tube about 8 or 10 inches in length and of calibre about equal to that of a No. 8 catheter, the end is securely closed by a ligature and a small oblique incision made with a sharp scissors as near as possible to the closed end. The incision should cut a small valve, with apex directed towards the closed end —the more oblique it is the better—and should at its base divide one-third of the circumference of the tube. This incision will be found to act as a most efficient valve, opening under very slight pressure from within, and preventing any regurgitation of pus or of the irrigated fluid. The tied end should be inserted to the very depth of the wound and the free end left projecting through the dressing; the number of tubes used must depend on the size and character of the wound, but it will generally be found that one, or at the most two, will suffice.

"In case of a perforating wound of a limb or of a wound with two openings widely separated, a very useful modification is to ligature the tube at its centre and cut a valve on each side of the ligature and pointing towards it. This is passed through the wound and the irrigation done from the ends. In this way any

fluid that is irrigated into the free ends of the tube must certainly find its way to the very bottom of the wound and from there towards the surface.

*To secure the tubes in position*, a useful plan is to make a small independent incision through the skin near the edge of the wound just large enough to grip the tube without occluding its lumen, and the free end of the tube is drawn through this after the tied end has been passed to the bottom of the wound. The free ends of the tube are left outside the dressing and the irrigating fluid passed into them by means of a glass syringe. Gravity alone will generally suffice; if necessary, a little assistance may be given by using the plunger of the syringe."

For deep and inaccessible wounds, notably compound fractures of the femur, W. H. Taylor and N. B. Taylor (Brit. Med. Jrl., II, 1917, p. 453) recommend the use of a device which insures, even more consistently than the Carrel method itself, the direct and prolonged exposure of every part of the wound to a disinfecting solution whose concentration remains constant. They consider a reliable system of liquid right closure as essential in wound treatment, on the basis of the reflection that the resulting alternate tension and collapse in the wound are necessary to the deeper penetration of the disinfecting fluid and the production of automatic cleansing or "tidal" movements.

*Description of Device.*—A rubber bag, after the pattern of an ice bag, is used, and a soft rubber collar is formed in the center of the "top-sheet" T. A suction ring, S, is attached to the circumference of the top-sheet. Round the under surface of S a gutter is formed, the sharp rubber lips on either side of which are designed to grip the skin. A small tube, K, leads from the gutter to the space beneath the collar. A valve on this tube lets air pass from the gutter and holds the suction by blocking its return. The drainage tube from the wound connects with a cannula in the collar, whose

outer end connects with a common tube. This common tube divides into an inflow and outflow a few inches from the collar by means of a Y-piece. There is a clip on the inflow, and another clip on the outflow.

*To apply*, first paint the skin with a mixture of petrolatum, Canada balsam, and rubber dissolved in ether. These ingredients in equal parts make a soft elastic paste that is not too sticky. The device is laid on so that the suction ring rests on sound skin, with the wound more or less in the center. The washer, of plastic felt, is now moulded to the suction and pressed down all around until the rubber lips make contact everwhere with the skin. When the felt has hardened a little cotton may be tucked between it and the ring wherever contact of the lips is not perfect. The ring is very flexible, and its attenuated lips can easily be made to conform to an irregular surface. When the bandage is applied over all, the air which is thereby expressed from the gutter through the small tube cannot return on account of the valve. After connecting the drainage tube to the cannula the collar is closed.

*To flood the wound*, close the outflow, when the fluid overflows and extravasates into the space between the top-sheet and the top of the suction ring. Here the pressure operates to force the suction ring against the skin; additional to suction beneath the ring, which is still maintained by the valve.

*To suck the wound out*, close the inflow tube and open the outflow, when siphonage aspirates the wound, collapses the collar, and renews the negative pressure beneath the suction ring through the tube.

If the wound is a through-and-through one, a similar device, with its tube, but unprovided with a collar, is applied to the lower opening. Its suction ring is influenced, too, by a negative pressure in the wound.

A suction apparatus to surmount difficulty of drainage, to be used with Carrel's irrigation tubes, was recently suggested by George C. Sneyd, for wounds of a

cavernous type where a large retentive septic space is present and where counter-drainage is anatomically impossible. The suction tube has no sharp edge and bears a lateral hole one-quarter inch distant from its termination, which hole lies on the bottom of the wound. The wound is covered by a single layer of sterile gauze. The patient himself can attend to the apparatus. A clip on the suction tube allows the wound to remain filled with the disinfecting fluid for any desirable period.

As a simplification of the Carrel-Dakin treatment of wounds, Dimond and McQueen devised for individual separate cases a narrow-necked bottle to replace the ampules and apparatus recommended by Carrel in his book. For the treatment of a large number of patients, they devised a system of siphonage with automatic flushing and refilling, so that once started no attention is required. This method requires only that the reservoir should be kept supplied with fluid. The automatic flushing from each of the two bottles, neither of which need be of a greater capacity than four ounces, does not require any further supervision. (For detailed description and illustrations, interested readers are referred to the Brit. Med. Jrl., II, 1917, p. 387).

*Modification of Carrel Apparatus.*—Rolland (La Presse Médicale, No. 59, 1917, p. 627) recommends a simple and inexpensive contrivance, by means of which efficient wound irrigation according to Carrel can be accomplished with the ordinary hospital equipments, at a minimum outlay. The apparatus consists essentially of a graduated flask, with an opening of 60 cm., which admits a rubber stopper, pierced by three holes, through which pass three glass tubes. The drop-counter consists of a glass tube of medium diameter, tapering at its lower extremity. It is connected with the container by a rubber tube of 15 cm., which is provided towards its middle with a Murphy screw clamp, serving for the regulation of the drippage. The glass tube, of an external diameter of 5 mm. and slightly exceeding in length

(about 8 cm.) the total height of the flask with its rubber stopper, is connected by a rubber tube to the curved glass tube, which is attached to the upper portion of the container. By plunging this tube more or less deeply into the container, the amount of the overflow can be regulated. It also serves to prevent any overflow in case of obstruction of the irrigation tubes of the wound or of the siphon.

The siphon consists of a U-shaped glass tube of 5 mm. external diameter. One of its branches plunges down to the bottom of the container. The other longer branch must reach about 5 cm. below the bottom of the container. To this siphon is attached a rubber tube, which conducts the liquid into the wound.

Three objections have been raised to the use of soda hypochlorite solutions:

(1) Their irritative effect upon the skin.

(2) Their brief efficiency.

(3) The necessity of uninterrupted contact with all surfaces of the wound.

For the removal of these and other minor objections, the dichloramin-T in oil method was devised by Dakin. The technic is greatly simplified, as compared to the hypochlorite procedure, and the quantity of dressing material needed is reduced by more than two-thirds. It is probable that the newer method would have replaced the hypochlorite solutions, but for superior results in war practice obtained from the latter and their specially trained hospital staff. In civil experience, the results of the dichloramin-T in oil method surpassed those of the hypochlorite method.

### Dichloramin-T in Oil Method

The chemical name of the double chloramin used is paratoleum hypochlorite (toluene-parasulphondichloramin). Commercially, it is known as chlorazene. The germicide is dissolved in chlorinated eucalyptol instead

of water, because synthetic chloramins will rapidly form inactive compounds with tissue proteins in the wound exudate. Similarly, chlorinated liquid paraffin may be added. The oils are chlorinated to limit their decomposing action on the dichloramin-T. The dissolving of the dichloramin-T in chlorinated eucalyptol insures a very gradual liberation of the bactericide, extending over 18 to 24 hours, instead of the 30 to 60 minutes' activity of the hypochlorite solutions.

It is claimed that the rate of decomposition of dichloramin-T in eucalyptol in a colored bottle is only 25 per cent. for the period of one month. In addition to its stability, this synthetic double chloramin compound has the advantage over the hypochlorite solution of being non-irritating to the skin. Application of the dichloramin-T in oil once in 24 hours is sufficient. The method permits of dependent drainage.

The basis of dichloramin-T is para-toluene-sulphochlorate, a by-product in the manufacture of saccharine.

The solution can be prepared by any reliable chemist.

First Method of Preparing Dichloramin-T.—Chlorinated lime (from 350 to 400 gm.) of good quality is shaken with two liters of water on a shaker for half an hour, and the mixture is then allowed to settle. The supernatant fluid is siphoned off and the remainder filtered. Powdered toluene-parasulphonamid, 75 gm. (the crude product may be used), is then added to the whole of the hypochlorite solution and shaken till dissolved. The mixture is filtered, if necessary, placed in a large separating funnel, and acidified by the gradual addition of acetic acid (100 c.c.). Chloroform (about 100 c.c.) is then added to extract the dichloramin, and the whole is well shaken. The chloroform layer is tapped off, dried over calcium chloride, filtered, and allowed to evaporate in the air. The residue is powdered and dried in vacuo. It is sufficiently pure for most purposes, without recrystallization.

The sodium toluene-parasulphochloramin, which is sold under the trade name of chlorazene, may be used instead of the toluene-parasulphonamid.

Second Method of Preparing Dichloramin-T.—Fifty gm. of para-toluene sulphonamid are dissolved in 500 c.c. of water, and 100 gm. of sodium acetate and 100 c.c. of chloroform are added. The container is immersed in cold water, and a rapid stream of chlorine is passed in until the mixture is saturated. The mixture is allowed to stand a few hours, and if the odor of chlorin disappears, more of the gas is passed in. If necessary, more chloroform can be added to dissolve the dichloramin. From this point on the procedure is the same as in the preceding method.

Preparation of Chlorinated Eucalyptol.—Eucalyptol, *not eucalyptus oil*, must be used. Five hundred c.c. are treated with 15 gm. of potassium chlorate and 50 c.c. of concentrated hydrochloric acid. After twelve hours the oil is well washed with water and sodium carbonate solution. Dry sodium carbonate is added to the oil, and the mixture is allowed to stand 24 hours. It is then filtered and dried with a little calcium chlorid.

Preparation of Chlorinated Paraffin Oil.—Five hundred c.c. of commercial liquid petrolatum are treated with 15 gm. of potassium chlorate and 50 c.c. of concentrated hydrochloric acid. The mixture is exposed to the light and allowed to stand over night. It is then put into a separatory funnel, and washed successively with water, sodium chloride solution, and water. The opalescent oil is tapped off, a lump or two of calcium chloride and 5 gm. of charcoal are added, and the oil is filtered with suction.

Concerning the amount of liquid petrolatum which can be added to the eucalyptol solution of dichloramin-T, Dakin found, on the basis of experimental evidence, that for solutions destined to be kept for any length of time no more than an equal part of liquid

petrolatum should be added to a 15 per cent. solution of dichloramin-T in eucalyptol. Mixtures destined for immediate use may contain as much as two parts of liquid petrolatum to one part of the 15 per cent. eucalyptol solution. In his work, a solution was used made up of one part of liquid petrolatum and two parts of 15 per cent. solution of the dichloramin-T in eucalyptol.

Employment of Dichloramin-T. — The simple technique is carried out as follows: A careful surgical trimming of the wound is done at the primary dressing. All infected and suspicious foci are excised, and all dead or dying tissues are cut away. Superficial wounds are exposed to the action of dichloramin-T by means of a spray atomizer. Into deep wounds the germicidal liquid is poured as into a cup. Wounds with two openings are treated in the same manner, the lower orifice having been temporarily closed with gauze, which is, after the treatment is removed, for the re-establishment of dependent drainage, a powerful physiological ally in the fight of the organism against the infection. Only a few layers of gauze should serve as wound coverings, so that the oil may be taken up by the dressings. One daily application of dichloramin-T in oil is sufficient. A renewal of the treatment is not required before the end of twenty-four hours, for large deep wounds, while one dressing for every 48 to 72 hours suffices for simpler or more superficial wounds. All wound pockets and recesses are reached by the oily solution of dichloramin-T. Infected tracts and recesses can be wiped out by means of cotton swabs dipped into the solution.

Ordinary hard rubber or all-glass spray atomizers should be used. Chlorine attacks metals, so that metal atomizers are not recommended. Irrigation tubes are unnecessary, as the dichloramin-T solution contains an abundance of available chlorine and does not have to be renewed every few hours.

The conclusions arrived at by Professor Sweet, work-

ing with the United States Army Base Hospital No. 10, in France, show that Dakin's dichloramin-T, in solution in eucalyptol and paraffin oil, is of great advantage in wound treatment, because:

(1) It saves the pain of wound dressing.

(2) It effects an appreciable saving of dressing material.

(3) The amount of solution needed is of small bulk.

(4) The number of wounds which a surgeon can dress in a given time is far greater than by any other method.

(5) The elimination of the Carrel tube simplifies the dressing and the problem of transportation of the wounded.

(6) The elimination of the Carrel tube saves the time taken by the nurse for the periodic flushing.

Dichloramin-T is a stable product, and its solutions have been kept in the dark for 132 days, remaining practically unchanged; when exposed to daylight, the strength was only very slightly diminished. Other advantages, aside from its strongly bactericidal action, are its high solubility in water, which enhances its practical usefulness, and its freedom from coagulating properties toward proteid matter. Necrotic tissue is dissolved by the chlorin in dichloramin-T, and reliable hemostasis must be secured by vascular ligature, in order to guard against disintegration of the clot and secondary hemorrhage.

Preparation of Chloramin Solution.—Dissolve 140 grams (dry) of sodium carbonate, or 400 grams of the crystallized salt, in ten liters of tap water. Add 200 grams of chloride of lime. Shake the mixture, and after half an hour siphon off the clear liquid from the precipitate of calcium carbonate and filter through a cotton plug. Add 40 grams boric acid to the clear filtrate. The solution is now ready for use, and should not be kept longer than a week. It contains 0.5 to 0.6

per cent. hypochlorous acid. (Prof. Cohen, of the University of Leeds.)

Chloramin paste contains 8 per cent. of sodium stearate and 4 to 15 parts per 1,000 of chloramin-T.

*Preparation of Chloramin Paste.*—Boil a liter of distilled water and add 80 grams of stearic acid. When this has melted, gradually add enough caustic soda to saponify the fatty acid, and after complete solution add 4 to 10 gm. of chloramin-T, according to the concentration desired. The mixture is then placed in a mixing machine and shaken until thoroughly cooled. The paste is a smooth, snow-white cream. It is found by Daufresne to be sufficiently active and stable for use in the treatment of wounds and for the promotion of wound sterilization.

Chloramin is a highly reactive substance, and should not be used in combination with other antiseptics. It decomposes alcohol as well as hydrogen peroxide.

*Technique for the Application of Chloramin Paste.*—"The chloramin paste is designed to maintain in an aseptic condition wounds which have already been disinfected, or to sterilize slightly infected wounds. It should only be applied to wounds which yield small quantities of secretion, have little or no necrotic tissue, and little or no infection. Neutral sodium oleate is poured on to the wound and the surrounding skin from a flask with a small opening. The granulations, the epithelial edges, and the skin are gently swabbed with a piece of absorbent cotton attached to a forceps. By this means an excellent cleansing process is effected. The patient should feel no pain: any suffering indicates either that the sodium oleate is incorrectly prepared or that the cleansing is imperfectly carried out. The sodium oleate is removed with a plug of cotton soaked in water, and the surface of the skin is dried by carefully applying a compress of absorbent gauze. A sufficient quantity of chloramin paste is withdrawn from the receptacle by means of a sterilized wooden spatule

and applied to the surface of the wound to the thickness of at least 1 cm. It should cover not only the granulations, but also the epithelial edges and part of the surrounding skin. If the wound is deep and anfractuous, the tube containing the chloramin paste is introduced into the opening, and sufficient chloramin paste is expressed to fill the cavity. But no pressure should be applied during the process. A compress of dry gauze, which should be much larger than the wound itself, is next placed over the chloramin paste. The compress is applied to the surface of the skin and attached to it by means of two or three strips of adhesive plaster. It is important that the gauze should be placed exactly over the wound, for if the bandage is shifted the gauze will introduce bacteria from the surrounding skin on the surface of the granulations and reinfection will ensue. Above the gauze is placed a piece of absorbent cotton enveloped in gauze. The dressing must not be compressed by bandages and should be renewed every 24 hours. The wound is washed out with sodium oleate every day or two, depending on the condition of the skin. The application of chloramin should be painless; any sensation of pain signifies technical error on the part of the surgeon. The bacteriological condition of the wound is examined every day in film preparations of secretions taken from various parts of the wound." (Carrel and Hartmann, Jrl. Exp. Med., July 1, 1917, p. 95.)

Stable hypochlorite solutions can now be obtained without the need of a chemist to watch the titration, by looking in surgical periodicals for the advertisements of large and reliable manufacturing houses, which have devised various methods for the preparation of the Carrel-Dakin fluid and other solutions for the disinfection of wounds.

*Preparation of Modified Hypochlorite Solution.*— Extract 25 grams of pure calcium hypochlorite with a sufficient amount of water at a temperature of 50° C.

to yield finally 1,000 c.c. of solution. After filtration, add 8 grams of sodium chloride or 12 grams of magnesium chloride, then gradually 2 to 8 grams of lactic or phosphoric acid, until the solution becomes slightly acid.

This preparation can be employed warm and is useful in the prevention of suppuration in presumably infected wounds.

*Preparation of Magnesium Hypochlorite Solution.*— Dissolve 190 grams of magnesium sulphate in two liters of water, and let the mixture act on 100 grams of calcium chloride which have also been mixed with two liters of water. Then filter, in order to separate the resulting precipitate of calcium sulphate. Let stand until this precipitate has become entirely settled to obtain a clear solution.

The employment of this disinfecting fluid is recommended on account of its strong antiseptic power, its non-caustic character in efficient dosage, its small cost, and its easy preparation. An excess of free magnesium is readily tolerated by the organism, in contradistinction from free soda or lime.

*Soap solutions* (common yellow soap, or, better, soft green soap of the British Pharmacopœia, in 2½ per cent. solution) have been used with the Carrel tubes for wound treatment in the Casualty Clearing Stations, with satisfactory results. In addition to their cheapness, these dressings are claimed to be much less painful than ordinary dressings, and require to be changed only once in three or four days.

## "Javelle Water" in the Treatment of War Wounds

The commercial preparation known as "Javelle (more correctly Javel) Water," a solution of chlorinated potassa, was at first considered as valueless in the treatment of infected war wounds, on account of its

irritant properties in moderately strong solutions. Recent investigations, by Cazin and Krongold, have shown, however, that a solution of 15 grams Javelle water for each liter of water (containing only 0 gr. 042 per hundred of sodium hypochlorite, or 15:1.000), is well adapted to surgical purposes. This 15:1.000 solution showed a bactericidal power superior to that of Dakin's fluid, the irritant properties of which are probably due to an excessive proportion of sodium hypochlorite. In the Messimy Hospital the treatment of 510 cases of wound infection—including 155 compound fractures and 286 deep wounds of soft parts, for the most part with very extensive lesions—with Javelle water led to recovery of all but three of the patients, or 507 recoveries. (La Presse Médicale, I, Nov., 1917, p. 632.)

*Preparation of Javelle Water.*—

| | |
|---|---|
| Potassium Carbonate ..... | 58 gm. |
| Chlorinated Lime ..... | 80 gm. |
| Water (*a sufficient quantity* to make about *one thousand milliliters*) ..... | 1000 mils. |

Mix the chlorinated lime intimately with *four hundred milliliters* of water. Dissolve the potassium carbonate in *three hundred milliliters* of boiling water, and pour the hot solution into the mixture first prepared. Shake the flask or bottle well, stopper it, set aside to cool, and then add sufficient water to make the product measure *one thousand milliliters* and filter. Keep the solution in well-stoppered bottles, in a cool place and protected from the light.

For use in wound treatment, dilute the fluid to a strength of 15:1.000 parts of water. This dilution, as shown by the French observers, makes a very practical solution, although Javelle water was at first thought to be inapplicable on account of its excessive alkalinity and irritant properties.

In connection with the alleged occurrence of secondary hemorrhage under certain modern forms of wound treatment, Bashford endeavored to ascertain the effect of immersion of living tadpoles in various dilutions of chloramin, Dakin's solution, eusol and flavine. For control, parallel experiments were made with iodin and mercury perchloride. It was found that chloramin, as compared to hypochlorite and eusol, is relatively less toxic to the animal. With hypochlorite, eusol, and chloramin, it is possible to separate the bactericidal effects upon the surface from the life-destroying action on the animal. With flavine in its strongest concentration, iodin, and mercury perchloride, the surface sterilization and life-destroying effect are inseparable. The local action of hypochlorite is apparently counteracted by an active circulation, which may be credited with a nutrient rôle, as a provider of protein, or with the mechanical removal of the hypochlorites before they can unite with and thereby destroy the living tissues. Simply expressed, an efficient circulation prevents the penetration of the chemically unstable hypochlorite solutions into living tissue.

### Hypochlorous Acid Preparations—Eusol and Eupad

The antiseptic action of hypochlorous acid, and its application to wound treatment, was pointed out in 1915 by Lorrain Smith, Dremman, Rettie, and Campbell, of the Department of Pathology in the University of Edinburgh. This hypochlorous solution is known as Eusol, which is standardized at 0.5 per cent. of hypochlorous acid, and was originally prepared on a large scale from dry bleaching powder and boric acid. In smaller quantities, eusol is advantageously prepared, at a moment's notice, by diluting and mixing two stable stock solutions, as follows:

*Preparation of Eusol.*—Take 135 c.c. of liquor calcis chlorinatæ (a 10 per cent. solution of bleaching pow-

der in water); dilute with water to 1 liter; add 10 grams of boric acid, and shake up till dissolved. The solution remains clear, and without further treatment is ready for use. If preferred, a saturated solution of boric acid may be stocked at room temperature; this contains 4 per cent. boric acid, therefore 250 c.c. gives the amount required for 1 liter eusol. In making eusol in this way, the 135 c.c. of liquor calcis chlorinatæ should be diluted to 750 c.c. and the 250 c.c. of boric acid solution added. This prevents the formation of the precipitate which occurs if boric acid be added to undiluted liquor calcis chlorinatæ.

*Preparation of Eusol for Intravenous Injection in Septicæmia.*—For this purpose, it is necessary to add sodium chloride in the proportion of 8.5 grams to the liter. In this case, therefore, the 135 c.c. of liquor calcis chlorinatæ would be diluted to 500 c.c. with distilled water, the 250 c.c. boric acid solution added, and also a solution containing 8.5 grams of sodium chloride dissolved in 250 c.c. of distilled water.

These methods of preparing eusol were published in the British Medical Journal, September 22, 1917, by J. Lorrain Smith, Ritchie, and Rettie, who say that since liquor calcis chlorinatæ keeps well, the method described above has suggested itself as a simple and convenient way of preparing eusol in any quantity desired. Each liter of the liquor yields at least seven liters of eusol.

(The quantities given in the prescription are calculated on a chloride of lime assaying 25 per cent. available chlorine, which is the average obtained from commercial samples at the present time.)

Eusol may also be prepared as follows: To 1 liter of water add 12.5 grams of bleaching powder, shake vigorously, then add 12.5 grams boric acid powder and shake again. Allow to stand for some hours, preferably over night, then filter off, and the clear solution is ready for use.

This solution contains:

| | PER CENT |
|---|---|
| Hypochlorous acid | 0.54 |
| Calcium Chlorate | 1.28 |
| Calcium Chloride | 0.17 |
| Total | 1.99 |

*Another Method of Preparing Eusol.*—Shake up 25 grams of eupad (equal parts of commercial bleaching powder and boric acid, intimately mixed and ground in a mortar) with 1 liter of water. Let stand for a few hours, then filter through cloth or filter paper. Keep the mixture in a closely stoppered bottle, and do not expose to light.

Eupad is the name given to hypochlorous acid in powder form, and consists of equal weights of finely ground bleaching powder (chloride of lime) and of boric acid.

Hypochlorous solution, electrically produced from hypertonic saline, was recommended as a strongly bactericidal disinfectant for septic wounds, by Beattie, Lewin, and Gee (Brit. Med. Jrl., I, 1917, p. 256). Their apparatus can be installed in any hospital or institution, and a supply of the solution produced at a very small cost. The lymph flow in the wound is encouraged by the hypertonic solution which is used for the production of the hypochlorite. Surface bacteria on septic foci seem to be destroyed almost immediately, and the stimulating action on the lymph flow tends to wash to the surface the more deeply situated organisms. This lymph increase is claimed to be very evident in the wounds treated with this solution.

*Mode of preparation of eusol*, according to Fraser and Bates (Jrl. of the R. Army Med. Corps, Vol. XXVII, 1916, p. 791): "In a Winchester quart bottle twenty-seven grams of dry bleaching powder were placed, and to this one liter of water was added; the

mixture was shaken, and twenty-seven grams of boric acid were added; the bottle was now filled with water, the solution was thoroughly shaken, allowed to stand for a few hours, and then filtered through cotton wool. The clear solution is eusol; it is slightly alkaline to litmus and it contains approximately 0.5 per cent. hypochlorous acid. The solution was stocked in air-tight stone jars."

The same writers report most gratifying results from intravenous injections of eusol, varying in amounts from forty cubic centimeters to seventy cubic centimeters in cases of autotoxemia subsequent to infection of a wound with gas-producing organism.

*Packing with salt sacks* (Gray's method), to which eupad powder has been added, is advocated in the treatment of septic gunshot wounds on the basis of good results in a large series of cases by Major Hull, of the Royal Army Medical Corps. A convenient method of combining the eupad with salt is to pack the wound with ordinary salt sacks sterilized in the autoclave and introduce into the middle of the sacks without touching the wound an unsterilized sack filled with eupad. (Sacks filled with eupad and salt in the proportion of one to three are destroyed in the autoclave owing to the corrosive action of the hypochlorous acid upon the fabric.) The solid salt sack consists of a two-walled sack of suitable size, made of bandage, between the layers of which four layers of gauze are placed. The interior of the sack is filled with salt and the tail of the bandage forms a drain. The sacks are made in different sizes, sterilized in an autoclave and stored ready for use. One or more of these sacks is used to pack wounds, the spaces between the sacks being filled with gauze. A tube of perforated zinc or rubber may be passed into the depth of the wound in case of large septic wounds. Six days may be said to be an average time for the sacks to remain in the wound.

"The successful results of this treatment largely de-

pend, as all treatment of septic wounds must, upon an early attack on the sepsis and upon the thoroughness with which it is possible to remove septic and necrosed tissue."

### Hypertonic Solutions (Lymphagogic Agents)

Substances which produce a free flow of lymph from the tissues with which they come in contact, thereby indirectly flushing the wound and diluting the toxins, have been recommended in the treatment of infected war wounds by Sir Almroth Wright and his followers. Although the lymphagogic effect increases in proportion to the strength of the salt solution, it is not desirable, on account of the resulting pain and irritation, to go beyond ten per cent. of salt, even in the case of sloughing wounds. In order to prevent the lymph coagulating on the siphon, bandages, and on the walls of the wound itself, citrate of soda is employed in combination with hypertonic salt solutions. Blood mixed with pus is prevented from clotting by five per cent. of salt mixed with 0.5 per cent. of citrate of soda. For the sole purpose of irrigation and removal of pus, the citrate is unnecessary.

In order to encourage a free outpouring of lymph from the whole internal and external surface of the wound, Sir Almroth Wright proposed an arrangement of bandages by means of which the irrigating fluid can be led into the wound where it is required; be distributed so as to wash down all walls; and then be carried away without any leakage into the bed. Loops of sterile bandages, previously soaked in a solution of 5 per cent. sodium chloride and 0.5 per cent. sodium citrate are introduced into the wound, after this has first been syringed out with the solution. The free ends of the bandage are carried out from the wound, to be inserted between plies of lint well soaked in the solution and folded over so as to form a thick pad. Finally, one or two tabloids of salt ought to be placed in between

the back layers of the pad, and over the top of all ought to come a layer of impervious protective tissue.

*Formula of Wright's Solution*

| | |
|---|---|
| Sodium citrate | 0.50 centigr. |
| Sodium chloride | 0.30 centigr. |
| Distilled water | 100 grams |

The employment of this "antiseptic anodyne" yielded excellent results in the experience of Dickinson, who has used it for two years in all sorts of cases, the wounds remaining clean and healing more rapidly than under the use of any other liquid.

Sir Almroth Wright says with regard to this lymphagogic solution, or rather with regard to a simple 5 per cent. salt solution, which he finds works in most cases equally well, that it has in this war proved itself permanently useful. When brought into action upon a dry and infiltrated wound, or a wound that is foul and covered with slough, it resolves the induration, brings back moisture to the surfaces, and cleans up the wound in a way that no other agent does. Applied in gaseous gangrene in the form of a wet dressing to incisions which have been carried down into infected tissues, it causes lymph to pour out of the wounds, and arrests the spread of the infection. And, again, applied in gaseous gangrene to an amputated stump in cases where it has been necessary to leave infected tissues behind, it reverses the lymph stream and draws out the infected lymph, saving life in almost desperate conditions.

The activity of salt solutions depends on this "phylacagogic" character, meaning their capacity of bringing the protective elements of the body, blood fluid and leukocytes, into application in the wound.

### Salt Pack Method of Wound Treatment

The salt pack treatment of wounds was introduced by Colonel H. M. W. Gray (Brit. Med. Jrl., I, 1916,

p. 1) for the purpose of promoting a lymphagogue action and obviating the need for elaborate drainage or continuous irrigation. As to results of the treatment with salt pack, Donaldson and Joyce write in *The Lancet* of September 22, 1917: "The adoption of this method has considerably curtailed the patient's period of convalescence, and has, moreover, succeeded where other methods have failed, including the much-advocated Carrel-Dakin procedure."

The method is distinguished by its simplicity, the avoidance of daily dressing of the wound, the prompt development of healthy surface granulations, and rapid improvement of the general condition.

*Application of Tablet and Gauze Packs.*—"After the wound has been cleaned by operation, all the recesses of the wound (these recesses should be sought out by the finger) are filled, fairly firmly, with gauze wrung out of 5 to 10 per cent. salt solution, in the folds of which are placed numerous tablets of salt. Bloodclots which may form during the packing should be wiped away. The gauze should be packed in concertina-wise, a tablet being placed between every third or fourth fold. A fairly large, fenestrated rubber tube is placed so as to reach to the deepest part of the main cavity, which is then filled with gauze and tablets. The dressing is made flush with the skin and the tube projects slightly from its midst. The surrounding skin is painted with solution of iodine or other antiseptic application. Two or three layers of gauze are then used to cover the wound and surrounding skin. A suitable amount of absorbent cotton-wool is applied and a bandage wound on smoothly and firmly. Should pus collect in any isolated part of the wound, it is not necessary always to remove the whole of the pack, and thus to cause the patient unnecessary pain, and to jeopardize the healing of the rest of the wound. Irrigation and drainage of the affected part may be instituted. The rest of the 'pack' will probably become

loose in a few days. If it is suspected that any part of the wound will give trouble in this way, a drain down to that part should always be inserted."

In the answer to questions regarding saline treatment, sent to twenty-two hospitals, in July, 1915, tablet and gauze packs were judged to be best for deep and fairly recent wounds.

Warm solutions of sea salt or common salt, in a concentration of seven parts in a thousand, proved useful for the immediate treatment of war wounds, in the experience of Abadie (Archiv. de Chir., Tome XXIV, No. 5, 1915, p. 162). The application of the salt is preceded by careful mechanical cleansing of the wound, which is then freely irrigated with the physiological solution and finally packed with gauze strips soaked in a concentrated salt solution. For convenience, a stock solution of 140:1000 is utilized, which represents seven grams of salt for fifty grams of water.

*Mode of Preparation.*—Boil a liter of water in which have been placed 20 teaspoonfuls of common salt. Filter through sterilized cotton into a previously sterilized metal container. For use, pour 100 grams of the stock solution into a receptacle containing two liters of boiled water.

### Magnesium Chloride

Solutions of magnesium chloride (.12, 1 0/00) were shown by Delbet to exert a cytophylactic action on the organism, enormously increasing the phagocytic power of the white blood cells. The effect seems to be the more marked the closer the cells are to their normal condition. The solution is non-toxic, and has been injected without harm into the veins of animals. Used for wound dressings and in subcutaneous injections, magnesium chloride solution appeared efficient in Delbet's experience, and he credits this treatment with the saving of a soldier's thigh which had been condemned to amputation on account of arthritis of the kneejoint,

with shattering of the patella and the external femoral condyle. (Gazette Médicale de Paris, 1915, p. 70.)

*Physiological chlorinated solutions* of sodium or magnesium chloride are recommended by Cruet and Rousseau (La Presse Médicale, XXVII, No. 15, 1916, p. 116) on the basis of favorable clinical experience, such as absence of wound irritation, rapid disappearance of infectious foci, prompt cicatrization. The chlorinated solution is of a stable composition and can be employed either hot or cold.

*Preparation of Chlorinated Salt Solution.*—To 250 gr. of calcium chloride add 80 gr. pure sodium chloride or 120 gr. magnesium chloride in one half liter of water at 50°. The resulting homogeneous milky fluid is poured into a container holding ten liters and filled up with water at 50°. The fluid is siphoned off and filtered through cotton to free it from the insoluble substances. Into the still warm fluid pour 30 to 40 gr. of lactic or phosphoric acid until the reaction becomes neutral or slightly acid. Now close the container, to guard against the giving off of hypochlorous acid, which is to yield secondarily the corresponding chloride. The fluid becomes opaque on cooling through the formation of a precipitate of acid calcium lactate or phosphate. Filter the fluid when it is cold to free it from its phosphate.

*Mode of Employment.*—The solution is preferably employed warm (112 to 122° Fahrenheit), in intermittent or continuous irrigation, either pure, or better, diluted with ordinary salt solution or warm sterilized water. Aside from irrigation, the chlorinated solution may be applied to the wound in form of moist compresses and dressings.

## Sugar Treatment of Wounds

This method is receiving attention, especially on the part of Italian writers. Clinical experience has shown

that a prompt effect of sugar consists in diminution and disappearance of the purulent wound secretions, and this is followed by the disappearance of the germs from the wound. The result of this twofold action is the transformation of a septic wound into a healthy granulating surface. Although wound dressings with concentrated sugar solutions cause a diminution and even subsidence of suppuration, the discharge in the first few hours is slightly increased, due to the osmotic action set up by the presence of a concentrated sugar solution on the wound. This flow of lymph, far from being objectionable, serves on the contrary for the purification of the wound. The favorable effect of concentrated sugar solutions on infected war wounds is due to their local vasoconstrictor action as well as to their antiseptic properties.

### Collargol

Collargol has been employed, especially in German war hospitals, with satisfactory results in the treatment of septic wounds and suppurating tracts or bone cavities. Its action, like that of all colloid substances, is catalytic, its beneficial effects being due to its determination of a powerful leukocytosis. Collargol possesses no true bactericidal power, as germs can live and multiply in relatively concentrated solutions (1:2000).

The physiological methods of wound treatment include the use of ether, suggested by Distaso and Bowen (Brit. Med. Jrl., I, 1917, p. 259), on account of its marked stimulating power. "In the cases studied, two constant phenomena were observed, namely, the very early and striking appearance of large firm granulations (often in six hours), and the early bleeding of the surface of the wound." The wounds are firmly swabbed when dressed, especially those with cavities or deficient drainage. Auto disinfection of wounds by irrigation with ether solution (2 per cent.) is claimed to quicken the healing of wounds to a striking degree.

### Bipp (Rutherford Morison's Method)

The name was chosen by Rutherford Morison for reason of brevity and because it indicates the constituents of the bismuth iodoform paraffin paste. Bipp is bismuth subnitrate or carbonate, 1 part, iodoform 2 parts, paraffin in quantity sufficient to make a soft paste.

The Morison treatment, in conformity with the most advanced surgical views, consists primarily in the mechanical removal of all necrotic material and tissue detritus from the surface and interior of the wound. Bloodclots, wound secretion, bacterial and other contaminations are removed through energetic friction of all wound recesses, and after the wound has been dried with alcohol, the antiseptic paste known as Bipp is spread over the wound surface and rubbed in. The wound is then sutured, closed, dressed, and left to itself for about twelve days, after which time it is expected to have healed or nearly so.

Briefly, this treatment consists in thorough cleansing of the wound and its surroundings, followed by the use of antiseptics, in form of:

(*a*) Carbolic lotion, 1:20, or other antiseptic washes, for the skin.

(*b*) Cleaning with alcohol (methylated spirit).

(*c*) Antiseptic paste (Bipp) for the wound.

*Composition of Bipp Paste*

| | |
|---|---|
| Iodoform | 440 grams |
| Bismuth subnitrate | 220 grams |
| Paraffin | 220 grams |

M. S. A.

The bismuth and paraffin are sterilized by dry heat at a temperature of 120° C. for half an hour; the bismuth after cooling is mixed with the iodoform in a mortar which has been sterilized by means of boiling water and formalin. The paraffin is added to the mixture at a temperature of 90° and thoroughly mixed,

then put into specially made collapsible tubes with nozzle ends, holding 40 to 80 grams. The paraffin used should be semi-solid, odorless, and tasteless, melting-point 45° C., free from acidity and carbonizable organic impurities. The iodoform should be free from moisture, acids, and fixed impurities. It is also necessary that the bismuth be chemically pure, free from arsenic, and care taken in sterilizing that the temperature does not rise too high, otherwise nitrous fumes will be evolved. A paste made by this method is found to be fairly solid in consistency, shows no signs of separation or decomposition, and is perfectly sterile.

*Modified Formula for a Paste of Softer Consistency*

| | |
|---|---|
| Iodoform | 440 grams |
| Bismuth subnitrate | 220 grams |
| Paraffin base | 220 grams |

M. S. A.

Paraffin base:

| | |
|---|---|
| Paraffin melting-point, 45° | 19 parts |
| Paraffin lig., specific gravity 880 | 40 parts |

In the *preparation of Bipp paste* the powders are mixed together in a mortar, and the liquid paraffin incorporated. The quantity of liquid paraffin required varies according to the bulk of the powders, the bismuth in particular being liable to considerable variation in bulk. A sufficient quantity should be added to form a paste. It is then advisable to rub down the paste, in small quantities at a time, on a slab with a spatula, to insure freedom from grit and dry particles of powder.

The technic of application is very definite and must be carefully carried out in both its phases:

(1) Under an anesthetic, usually open ether, cover the wound with gauze wrung out of 1 to 20 carbolic acid, and clean the skin and the surrounding area with the same lotion.

(2) Open the wound freely, and if possible sufficiently to permit of inspection of its cavity.

A guide—a finger is the best if the size of the wound permits of it, and if not a thick probe—should be introduced to the bottom of the wound and held there and fully exposed. In doing this, special regard must be paid to nerve trunks and muscular branches of nerves. Cleanse the cavity with dry sterile gauze mops, Volkmann's spoon, etc., and remove all foreign bodies.

(3) Mop the surrounding skin and the wound cavity with methylated spirit and dry it.

(4) Fill up the whole wound with Bipp, rub it well in with dry gauze. Then remove all excess, leaving only a thin covering over the wound surface. Dress the wound with sterile gauze, and cover all with an absorbent pad, which is held in position by sticking plaster and a bandage.

Though it is desirable to see the bottom of all wounds, it may be occasionally unwise. A through-and-through wound, with small entrance and exit openings, may be generally cleansed satisfactorily by passing a long strip of gauze through it and pulling this to and fro as a first step, next by doing the same with a strip of spirit gauze, and finally depositing a layer of Bipp on the inner surface of the wound by covering a long strip of gauze with the paste, passing it through the track and rubbing in the medicament by pulling the gauze backwards and forwards again and again.

The only possible objection to the free use of Bipp as an application to open wounds is the liability to absorption and production of iodoform poisoning, which has been noted in a very small number of cases. Idiosyncrasies against iodoform occur, especially among youthful males.

Sir Berkeley Moynihan, in a recent paper on surgical experiences in the present war, says that Rutherford Morison's method is widely practised in the base hospitals in England, and by many surgeons considered

the most satisfactory of all. This method of wound treatment, in the opinion of Sir Alfred Pearce Gould (Brit. Med. Jrl., II, 1917, p. 677) constitutes the highest attainment yet achieved.

The following results have been obtained by means of this up-to-date method of wound treatment:

(1) Healing of large infected wounds, without special drainage, and without change of dressings up to a period of six weeks.

(2) Safe closing of such wounds by sutures, at any stage of their repair.

### Iodated Starch

An iodated starch solution, which seems to possess antiseptic properties analogous to those of Dakin's fluid, has recently been recommended for irrigation of infected wounds, according to the Carrel method, on the basis of very favorable results, by Lumière (Journal de Méd. et de Chir. Prat., November 10, 1917, p. 868). This solution does not irritate the tissues, so that these do not have to be protected, nor does it burn the bedding, sheets, etc., which are rapidly ruined by the hypochlorite. The liquid is prepared as follows:

*Mode of Preparation of Iodated Starch Solution*

| | |
|---|---|
| Soluble Starch ..... | 25 grams |
| Boiling water ..... | 1000 grams |
| Iodated Iodin Solution, 1% .... | 50 c.c. |

### Flavine (Acri- and Pro-flavine)

The employment of antiseptics such as flavine, or brilliant green, is not, strictly speaking, a modern method of wound treatment, the novelty feature being represented by the new antiseptic itself, in its improved combination of highly germinated properties with inoffensiveness towards the tissues of the body.

Flavine, originally named trypaflavine, on account of its therapeutic effect on trypanosome infections, is

chemically diamin-methyl-acridinium chloride. As one of the acridine series, flavine, for technical reasons, is designated as acri-flavine. Its solutions may be boiled or heated up to 120° C. in the autoclave, as the substance is a fairly stable compound. Great expectations were placed on it, and it was found efficient by Ligat (who for some time used flavine exclusively for septic cases) in heavily infected wounds with free drainage of pus. Mixtures of acridine dyes analogous to flavine also yielded some good results in the treatment of septic war wounds. In the experience of Kellock, who injects one to two drachms of a 1:1000 solution through his modified tubes twice in 24 hours, the use of flavine was followed by very satisfactory results in some highly septic cases. In the treatment of the later stages of war wounds, however, flavine cannot be classed as a success, although it apparently has its uses as a first dressing. The abdominal or thoracic cavities will tolerate considerable amounts of flavine solution without giving evidence of the least toxic effect. Fleming found, however, that when flavine 1 per cent. is introduced into a closed cavity in the animal body it loses its antiseptic power within two hours, and he points out that much more rapidly then will the 1:1000 solutions recommended for use lose their potency.

The series of tests, reported by Drummond and McNee (Lancet, II, 1917, p. 640), comprises over 120 wounds, for the most part caused by fragments of shells or bombs, and including soft parts wounds, compound fractures, miscellaneous regional wounds of the abdomen, chest, head, and joints. A number of the cases, chiefly compound fractures and external muscle injuries, were treated with flavine in the Carrel method of intermittent irrigation; the perforated tubes were irrigated with the solution every four to six hours. Flavine was at first employed diluted in normal saline solution, in which the powder is readily soluble, in a strength of 1:1000. Later on it was found that the

results were equally good when the stronger solution for the first dressing was followed by the employment of a solution of 1:5000 for all later applications. In some cases, where the Carrel irrigation method was used, the strength of the solution was further reduced to 1:10,000.

The strong bactericidal properties of this chlorine compound were first pointed out by Browning and Gilmour. But the claims of Browning and his co-workers from the Bland-Sutton Institute of Pathology of the Middlesex Hospital, London (Brit. Med. Jrl., I, 1917, p. 73), that flavine is a very potent germicide, especially in the presence of serum, and does not retard phagocytosis, are not endorsed by Hewlett (Lancet, II, 1917, p. 493), and Fleming (Brit. Med. Jrl., II, 1917, p. 341). Criticizing Browning's technic, Hewlett shows that, according to his own experiments with a much larger number of bacteria, the germicidal value of flavine is very much lower than was originally assumed. Fleming, working in the research laboratory of a base hospital in France, found that flavine has a very destructive effect on leukocytosis, and that if the action on leukocytes and bacteria be each tested for 24 hours its leukocidal action is far in excess of its bactericidal action. According to his findings, flavine in 1:500 solutions is usually unable to sterilize in 24 hours an equal volume of pus from a wound, there evidently being something in pus which prevents the action of flavine on the microbes, presumably because it is absorbed by the pus cells, which have a greater attraction for flavine than have the microbes. A persistent infection with coliform bacilli is noted in the later stages of war wounds treated with flavine preparations, and pyocyaneus infections are likewise common.

The mode of application of flavine will be considered under the heading of proflavine.

Proflavine.—Proflavine is a preliminary product in the manufacture of acriflavine, or flavine, and its

preparation is therefore more simple and less expensive. It was tested by McNee, Hadden and McCartney, in a mobile laboratory, following the same plan as in the testing of acriflavine. A series of 43 cases, and altogether 60 wounds, with a large percentage of very severe injuries, were treated with proflavine. These cases were under the care of the surgical officers of a Casualty Clearing Station, and included seven injuries of large joints, ten severe compound fractures of limbs, and four lesions of large blood vessels (with special reference to the vascular injuries; after dealing with the vessels, all the wounds were completely sewn up after treatment with proflavine, and all healed without the least trouble). The outcome of the tests showed no difference in the properties of acriflavine and proflavine.

*Mode of Application of Flavine (Acriflavine and Proflavine).*—The employment of these antiseptics must be preceded by the excision of all traumatized tissue, with careful mechanical cleansing of the wound. In order to guard against agglutination of the red blood cells, flavine solutions should not be used in stronger concentration than 1:1000. A flavine solution of 1:1000 in normal saline serves for the primary application, followed later by the use of a more dilute solution of 1:5000 or still weaker concentration. To large open wounds, flavine may be applied in form of gauze soaked in the solution as a first dressing, which need not be changed for two to three days.

### Brilliant Green, Paste and Lotion

Brilliant green is chemically a triphenylmethane compound; commercial brilliant green is the sulphate. Substances of this class possess a very strong activity against wound infections with cocci, whereas B. coli infections occasionally prove intractable. Brilliant green stimulates the formation of healthy nodular granulation tissue, which is characterized by its ex-

uberance and its bright red color, and the employment of brilliant green paste has been suggested as possibly useful for promoting the filling up of large deep wound cavities.

*Composition of Brilliant Green Paste.*—This non-poisonous paste, which was introduced by Captain Wilson Hey into the treatment of infected war wounds, is composed of boric acid, liquid paraffin, French chalk and brilliant green.

*Mode of Application.*—As pointed out by Captains Rendle Short, Arkle and King, the paste is only to be applied when it can be applied completely. They find that Hey's method of staining the wound by injecting through a Carrel's tube with a 1:200 watery solution of brilliant green is a very valuable aid to complete excision. Brilliant green paste should be reserved for such cases in which the wound can be freely opened and excised, with removal of all foreign bodies. The wound ought to be dry and not bleeding, but a certain amount of oozing can be checked by a gauze plug, preferably paraffin gauze, which is easier to remove. The paste should be rubbed in thoroughly. It soon washes off the skin or gloves. The wound need only be dressed about once in four days. The application of the paste is painless.

In the great majority of cases, in the experience of the above-mentioned observers, the wound was almost completely sterilized by brilliant green paste in three days, permitting the performance of secondary suture even in large wounds complicated by bone injury. Small completely excised wounds can be primarily sutured after the application of brilliant green.

"By this method we have been able, with fair consistency, to obtain healing within a fortnight of cases of compound fracture, even when complicated by joint injury, big buttock wounds and deep muscle wounds. We have excised an elbow-joint full of pus, and obtained primary healing in a fortnight."

Infected war wounds surfaces may be swabbed with brilliant green 1:1000 and kept covered with gauze soaked in this solution. The introduction of brilliant green into closed cavities is not recommended. The control of infection by brilliant green is a relatively slow process, especially in infections associated with extensive inflammatory swelling, which will subside more rapidly when flavine is used. Large superficial infected wounds are especially amenable to brilliant green antisepsis.

The procedure followed by Ligat, in the case of suppurating wounds, consists in securing adequate drainage by free incision, when necessary, and then to irrigate with a 1:1000 solution of the antiseptic in normal saline; finally, the wound is covered with gauze soaked in the solution, and protective applied to prevent evaporation. Existing cavities are packed lightly with gauze soaked in the solution.

Brilliant green was used in conjunction with salt tablets, by Captain C. H. S. Webb (Brit. Med. Jrl., I, 1917, p. 870), in whose experience the usefulness of the saline pack is enhanced by the inclusion of some antiseptic in the dressing. The combination of the saline pack with the green gave better results than the use of one or other alone. It can also be used after the method of Carrel—½ oz. to 1 oz. of a 1:1000 solution being syringed down a tube or series of tubes leading into the depths of the wound. It is not so irritant to the skin edges as the hypochlorite solution.

*Preparation of Brilliant Green Ointment.*—Dissolve brilliant green, 8.75 gr., in rectified spirit 15 minims, and incorporate with soft paraffin, 2 oz., thereby making a 1 per cent. ointment.

*Brilliant Green Used as a Lotion.*—The brilliant green is dissolved in normal saline solution in the strength of 1 in 1,000. At this strength it can be used as a lotion, and gauze soaked in it can be applied to the wound as a dressing. It is non-irritant to the tis-

sues, while undoubtedly an active and efficient antiseptic, and it acts well in the presence of serum.

### Methyl Violet

Methyl violet (pyoktanin), after having been found useful in veterinary surgery, has been applied with favorable results to infected and suppurating war wounds. It stains and destroys the bacteria and the necrotic cells, by inducing an acid reaction and active desquamation. The wounds rapidly become clean and a frequent change of dressings is unnecessary. Used as a prophylactic agent, methyl violet serves to guard against tetanus and other infections in suspicious war wounds. The method has the advantage of simplicity and cheapness.

### Magnesium Sulphate

The practice of Morison and Tulloch (Jrl. of the R. Army Med. Corps, Vol. XXVII, 1916, p. 375), in recent wounds, both of bone and soft parts, has been to swab the wound freely with pure carbolic acid, packing it afterwards for twenty-four hours with gauze steeped in carbolic lotion (one in twenty). This, together with free and dependent drainage, has been frequently successful in obviating or minimizing sepsis.

This is followed at the end of twenty-four hours by the application of the magnesium sulphate dressing, which is painless and easily carried out. Even in the most septic cases the dressings need only to be changed twice a day.

*Mode of Preparation.*—A saturated solution of the salt has given the best results, both clinically and experimentally; forty ounces of magnesium sulphate (by weight) are dissolved in ten ounces of glycerine and boiling water, sufficient to make a Winchester quart (by measure). The glycerine must be added slowly while the solution is hot and stirred gently or the salt

precipitates on cooling. The solution is then sterilized in an autoclave and is ready for use.

*Application as a Dressing.*—In recent injuries the wound is freely opened up, any foreign body, bullet, portion of shell, clothing, etc., is removed, and the whole wounded surface is swabbed over with pure carbolic acid. In the case of fractures, the ends of the bone are treated in the same way, and free fragments of bone are removed. The wound is gently packed for twenty-four hours with gauze wrung out of carbolic lotion (1:20) and antiseptic wool applied as an outer dressing. At the end of this time the wound is dressed, the gauze plug is removed, the wound is syringed out with magnesium sulphate solution of the strength indicated above, no swabbing of the wound is done and the wound is loosely packed with sterile lint taken out of the magnesium sulphate solution, in which it is constantly kept. The strips of lint used are narrow (from half inch to one inch wide), so that the solution with which they are saturated comes in contact with all parts of the wound surface. A double layer of lint, wet with the solution, covers the whole of the surface wound. This is covered with a piece of jaconet and then cotton wool, the whole dressing being fixed loosely by a bandage. In the case of wounds of a later date, where sepsis and suppuration are fully established, the treatment by carbolic acid is omitted and magnesium sulphate solution is commenced at once. Dressings even in the worst cases are changed only at twelve-hour intervals, thus saving a patient much discomfort and trouble.

The effect on the wound is very striking. In two or three days pus has almost disappeared, sloughs begin to separate, and the whole surface presents a bright color. The granulations never become flabby or œdematous, but instead a firm vascular healing wound is seen. Scratching the surface of the wound with a probe hardly disturbs the vascular granulations. The growth

of epithelium from the edges of the wound proceeds vigorously, and the treatment may be continued with advantage until the entire wound is healed. The resulting scar is firm and elastic and seldom tends to contract or to become painful.

Magnesium sulphate solutions are not recommended for a first dressing for fresh wounds, but as a curative dressing in the succeeding phase of wound repair.

### Vincent's Powder

This boro-hypochlorite powder is especially recommended for the prophylactic dressing of contaminated wounds, and is considered by some war surgeons as extremely valuable for this purpose. The antiseptic action of the dry dressings is powerful, and the powder does not injure the body or the cell, being free from irritative, caustic, and toxic properties. War wounds are claimed to heal with remarkable regularity under its influence. Employment of this powder is both very simple and very cheap.

*Preparation of Vincent's Powder.*—

Desiccated Calcium Hypochlorite... 10 grs.
(Titration of 100 to 110 liters of chlorine.)
Pulverized Desiccated Boric Acid... 90 grs.
(Passed through a moderately fine sieve.)

Pulverize separately, mix with care, and keep the powder in colored glass bottles closed with a paraffin-coated stopper.

*Technique of Vincent's Method.*—The wound is carefully cleansed, all contused or necrotic tissues are cut away, the projectile and particles of clothing, etc., are removed. This is followed by irrigation with boiled water under pressure and accurate hemostasis. The antiseptic powder is then applied in all the recesses of the

wound, carefully exploring the different layers with the grooved catheter in order to expose all interstices to the action of the mixture, which serves at the same time as a hemostatic. The wound itself, the surrounding skin and the first layer of the dressings should be freely covered with the powder. Into wound channels with narrow openings the powder can be introduced by means of an insufflator devised by Vincent, with four glass cannulas of different caliber, through which a large amount of the powder can be blown into the wound. At the end of forty-eight hours the dressing is changed for the first time, and again renewed three or four days later. On account of the very profuse wound secretion which results, only vestiges of the antiseptic are in evidence when the dressings are changed. Wound drainage is not interfered with in any way, all secretions being, on the contrary, drawn to the surface. The antiseptic remains for many hours in contact with the wound, a noteworthy feature of this method, permitting it to exert a continuous disinfecting action.

In the extensive experience of Sauvage, infected war wounds presented a remarkably favorable aspect under the influence of this treatment (La Presse Médicale, 8 Nov. 1917, p. 644), and Martin (Jrl. de Méd. et de Chir. Prat., 10 Nov. 1917, p. 869) considers it as the antiseptic of choice in war surgery. After employing it in extremely severe and variegated cases, Sauvage finds that properly applied it counteracts in a remarkable way the grave infections which threaten war wounds in the beginning of their course. The application of the powder must always be preceded by careful surgical preparation of the wound. In the vast majority of cases such wounds present a good appearance and take an aseptic course. Should infection persist, which is exceptional, it appears to be greatly alternated, and is checked by another application of the powder. (Bull. de l'Acad. de Méd., LXXVII, 6 Nov. 1917, p. 548.)

**Sunlight and Ozone Treatment of Infected Wounds**

Heliotherapy, or sunlight treatment of war wounds, deserves to be more extensively employed as a physiological curative method, the routine adoption of which is urged by Dr. M. Cazin (Monograph, Paris, 1917) as a measure capable in many cases of greatly abridging the duration of the treatment of war wounds and essentially reducing the number of war invalids. Sunlight treatment, first recommended by Rollier in tuberculosis and traumatism, is most successful when the patients are exposed nude for many hours to the rays of the sun. Although total insolation is always to be preferred, local insolation with a graded action of the sun on the course of the wounds materially assists the processes of repair. The exposure to the sun must be direct, in the open air, in order to improve nutrition and promote oxydation, and total, including the entire body, the resistance increasing in proportion to the extent of the insolated surface. Insolation of the clothed body is cautioned against as liable to induce visceral congestion.

The insolation method should be carried out progressively, always beginning with the less sensitive lower extremities, also when the wound concerns the thorax or an upper limb. Observation of the following rules is recommended:

*Rules for Use of Heliotherapy.*—First day: Expose only the feet to the sun, during fifteen minutes, in three sessions, separated by intervals of from half an hour to one hour.

Second day: Altogether thirty minutes of insolation, of which fifteen for the legs, in three sessions at half-hour intervals.

Third day: Exposure of forty-five minutes in three sessions of fifteen minutes, of which five minutes each time for the thighs.

Fourth day: One hour's exposure, in three sessions of

twenty minutes each, of which only five minutes for the abdomen, always with an interval of half an hour between the sessions.

Fifth day: Three sessions of twenty-five minutes, of which five for the thorax, making altogether one hour and fifteen minutes exposure to the sun.

The total duration of the exposure is increased by fifteen minutes daily, adding five minutes to every session for each of the segments which have been exposed during the first five days. In this way a total is reached of three hours' sunbath in three sessions. The body must be sheltered for some minutes from the sun, however, until the appearance of a brown pigmentation permits a continuous exposure during three hours.

After exposure to the sun, Dr. Reinbold, director of the Evian Hospital, where the method is extensively utilized, leaves the wound exposed to the air for part of the day, merely covering it with a thin layer of sterile gauze. For the night, compresses moistened in sterilized water are added.

Aside from the analgesic action of the sunbath, its local effect promptly induces a change in the condition of the wound. In the second stage of the treatment, about the eighth to tenth day, the suppuration diminishes, after having notably increased following the first sessions, and healthy granulation tissue develops; the wound becomes dry and clean, its borders retract, and a zone of epidermization makes its appearance. Constant phenomena in the sunlight treatment of wounds are regional pigmentation, a change in the character of the pus, and an abundant serous exudate over the entire surface of the wound, which soon dries up more or less completely.

Atonic and indolent wounds, in the experience of Cazin, on exposure to the sun, became regularly covered with a layer of healthy granulations, and in other wounds, without an apparent tendency towards epidermization, an epidermal margin promptly appeared at

the borders and advanced without arrest towards the center of the wound.

Sunlight treatment was found to hasten recovery, not only in wounds of the extremities, but also in wounds of the thorax and abdomen. Excellent results were obtained in infected fractures, and in several cases where the bony lesions were such as to endanger the preservation of the limb, heliotherapy led to complete consolidation and perfect recovery. Some cases of infected fracture of both leg bones healed in a few weeks under sunlight treatment, after the condition had remained stationary for months, in spite of repeated interventions and all other treatments. The results of heliotherapy were equally favorable in joint infections, and in the cicatrization of amputation stumps with bony fistulas.

In Delbet's service, all wounds are exposed daily for as long as possible to air and light, covered only with a fourfold layer of gauze, without cotton or bandage. Very remarkable results were obtained with this simple treatment. Gravely infected wounds which yielded a highly positive pyoculture became transformed, so that in two days the pyoculture became entirely negative; in one instance, the wound secretions became in forty-eight hours not only bactericidal but bacteriolytic for the vibrio. This simple plan of wound treatment is warmly recommended by Delbet (La Presse Médicale, XXIII, 1915, p. 237).

Artificial light, in form of electric lamps, is always available, and in the experience of Chaput (La Presse Méd., XXII, 1914, p. 606) were found to be equally applicable as sunbaths for local use in burns and ulcerations. An ordinary electric lighting outfit provides a simple, cheap, practical, and highly efficient method of treating infected or gangrenous wounds, and it is suggested that this mode of treatment may find its uses in certain complications of war wounds.

*Ozone treatment of war wounds* is a very recent in-

novation, recommended on the basis of satisfactory and remarkable results by Major George Stoker, of the Royal Army Medical Corps (1917). The necessary portable apparatus for generating ozone employed by him is known as Andriolis ozonizer, which is called into operation by a four-volt battery animating a quarter-inch sparking Ruhmkorff coil. The oxygen passes from a cylinder through the ozonizer, and in doing so comes in contact with a metal armature, the effect of this being to transform the oxygen into ozone.

The treatment consists in the application of ozone to the affected parts. At first ozone causes an increase of this discharge of pus; later on the pus is replaced by clear serum, which at a still later stage becomes reddish or pinkish. Ozone has the particular power of disclosing dead bone, foreign bodies, septic deposits, and so forth.

*Mode of Application.*—The ozone is applied on the wound surface or to the cavities and sinuses for a maximum time of fifteen minutes, or until the surface becomes glazed. It is a strong stimulant, and determines an increased flow of blood to the affected part. It is a germicide, which destroys all hostile microorganic growth.

### Acetozone

*Acetozone*, or benzoyl-acetyl-peroxide, has been shown to be a potent disinfectant, and under its use numerous cases of septic wounds in the experience of Gore Gillon healed up in three weeks, after having resisted all other treatment for four or five months. It can be applied to deep wounds by Carrel-Dakin tubes, by the bath method, or in a waterproof bag, or by wet dressings of 10-grain strength solution, renewed two or three times a day.

*Mode of Preparation.*—(1) The solution must be made by adding 5 to 7 grains to 1 pint sterile water at 112° F., left to stand for two hours, and should not

be filtered. (2) Or a 10-grain to 1-pint solution can be used with dressings or Carrel-Dakin tubes, etc. (3) In very septic cases, swarming with anaërobes, etc., a 20-grain to 60-grain solution may be used. (4) It should be made fresh every seven days, and the bottle shaken before using.

Acetozone may be used cold as a bath; (*a*) containing 5 grains to the pint, (*b*) or as a 7-grain solution with one-third hot water added. Its action is very rapid; unhealed amputation stumps heal quickly if put into a bath of this solution for half an hour daily, and dressed afterwards with dressings of sterile lint or gauze soaked in the 10-grain solution. Used in a 20-grain solution it is an efficient sterilizer of the skin. (Brit. Med. Jrl., II, 1917, p. 909.)

### Delbet's Pyoculture

*Delbet's Pyoculture* (La Presse Méd., 1915, p. 239). —This method is based on the reflection that under general and local conditions so unfavorable as to preclude the patient's fight against the infectious microbes, these would presumably be extremely numerous and multiply abundantly in the wound secretions. Under better conditions, permitting a fight against the infection, the microbes would grow but slightly, perhaps less than in ordinary culture bouillon. Finally, in case the body conquers the infection, the microbes would hardly grow at all in the wound secretions, and perhaps be actually destroyed therein. There would thus be three phases, corresponding to the victory of the microbe: the fight between it and the body forces: the victory of the patient. This theory was borne out by practical experience.

*Technique of Pyoculture.*—A little pus is removed from the wound in the customary manner, and, with the contents of the pipette, a smear preparation and an inoculation of peptonized bouillon are made. The closed pipette and the inoculated test tube are then placed in

the incubator, and 24 hours later specimens are prepared from the contents.

A comparative study of these three preparations furnishes valuable information concerning the progress and the operative indications. The pyocultural findings supplement the findings in the first specimen, prepared immediately after the removal of the pus from the wound. The pyoculture is positive when the microbes are seen to multiply abundantly in the pus; an active bacterial growth, especially when more abundant in the pus than in the bouillon, has a serious prognosis and calls for surgical interference. In other cases the microbes do not develop in the pus, but grow well in the bouillon; this means that the pyoculture is zero and indicates an efficient fight on the part of the patient. This fight should be assisted but not hindered by therapeutic measures. In the last group of cases, the pyoculture is negative; the number of microbes in the pipette not only does not increase, but it actually diminishes, indicating that the wound secretions are not only bactericidal but bacteriolytic. The patient recovers through a process of autovaccination; and it is advisable to leave well enough alone, as this fortunate outcome could only be impeded by treatment.

### Vaccine and Serum Treatment of Infected Wounds

The fundamental principle of vaccine therapy, according to a definition by Sir Almroth Wright, is to exploit, in the interest of the infected tissues, the unexercised immunizing capacities of the uninfected tissues.

Vaccine therapy, judiciously employed, offers the following advantages:

(1) Increase of the general resistance. (2) Limitation of bacterial invasion to the immediate wound surroundings. (3) Heightened and hastened regeneration of tissues in the damaged territory

The following routine treatment is suggested by Kenneth Goodby (Lancet, II, 1916, p. 585) as a result of his investigations: Polyvalent vaccines should be prepared from stains of organisms isolated from the infected wounds, consisting of (1) streptococci (aërobic and anaërobic varieties), sensitized with antistreptococcal serum; (2) B. proteus; (3) B. lactis aërogenes; and (4) B. coli.

A mixed vaccine of sensitized polyvalent streptococcus 5,000,000, with B. proteus 10,000,000, should be given to all septic cases when admitted, pending the bacteriological report. In cases of gas gangrene, streptococcal vaccine combined with B. proteus and B. lactis aërogenes should be used in strength of 10,000,000 each. The inoculations as indicated by the bacteriological examination should be repeated on the third day, and the dose raised to 10,000,000 streptococcus with 20,000,000 of the appropriate bacilli. Meanwhile, autogenous vaccine may, if necessary, be prepared for special cases when desirable; otherwise the appropriate polyvalent vaccine may be continued as determined by the bacteriological indications.

*Serum Treatment of Leclainche and Vallée* (Bull. de l'Acad. de Méd., 1915, p. 280).—On the basis of experimental investigations, it was shown that the bacterial agents in wounds can be made to undergo digestion, by sensitizing the organic cells with a septic serum, the cells retaining their full vitality and capacity to build up repair tissue. The polyvalent serum of the French investigators contains the antibodies corresponding to the agents of the various inflammations and suppurations, represented by several varieties of staphylococci and streptococci, coli bacilli, pyocyaneus, proteus. To these aërobic germs they added several types of anaërobes, the perfringens and septic vibrio. The polyvalent serum is obtained from horses which have been immunized against the germs of the different suppurations. It was originally intended for purely

local use as a direct application to infected wounds, in form of injections or dressings; but it has also been successfully employed in hypodermic or intravenous injections, in certain cases of staphylococcus and streptococcus septicæmia. Cazin (Paris Médical, XI, 1916, p. 262), in a series of observations, noted excellent effects of the polyvalent serum on infected wounds, more particularly streptococcus infections, and recommends it not only for its local action, when used in wound dressings, but also for its general action in septicæmia, when hypodermic injections are applied outside the seat of the lesions. No serum reaction was observed to follow on direct application of the serum to the wounds in fairly large and frequently repeated doses. Unless improvement is promptly manifested, there is no advantage in continuing this treatment.

A large number of septic cases under the care of R. H. Jocelyn Swan (Lancet, II, 1916, p. 859) were treated as a routine measure with a mixed polyvalent vaccine of proteus and streptococcus, with highly satisfactory results. Appropriate combinations to suit a given case are administered later on, according to the findings on examination of the wound conditions. He is convinced of the great use of vaccines as a supplementary treatment to surgical measures in septic wounds, and is satisfied that the routine employment of a polyvalent vaccine of proteus and streptococcus is of value in inhibiting the tissue necrosis caused by anaërobic bacilli, which are so commonly associated with these organisms in gunshot-wound infection.

"I have found the greatest value of vaccine therapy in the treatment of complicated septic fractures of long bones and of fractures which open into joint cavities. In the treatment of septic compound fractures I now make a routine practise of giving a preliminary dose of polyvalent vaccine (proteus and mixed streptococci), and then after two or three days freely open the wound to secure adequate drainage, approximating the frag-

ments and only removing those fragments which are undoubtedly completely separated, at the same time taking advantage of the opening of the wound to obtain further bacteriological examination. Extension apparatus of various types of splints suitable to the individual fracture are applied, but should the resulting position of the fragments prove on further radiographic examination to be unsatisfactory, I have no hesitation, after a further few doses of specific vaccine, in securing the bone fragments in apposition by means of silver wire or even bone plates in the presence of sepsis, and can now look back on a series of cases in which not only have limbs been saved, but bones in good alignment and functional use. Further, the result as regards sinus formation and necrosis of fragments of bone in the seat of fracture have been more appreciably lessened in those cases in which vaccines have been used than in those in which exactly similar surgical measures were employed without the assistance of vaccines."

Antiseptic vaccines have proved especially useful in the safeguarding of tissue adjacent to an infected wound against bacterial invasion. Excellent results have also followed their employment as adjuvants to a well-established and efficient physiological drainage.

*Technic of Wound Dressings with Polyvalent Serum.* —The employment of this method excludes the use of all antiseptic agents, as these without exception interfere with the phagocytic and opsonizing action of the serum. The wounds should therefore first be washed with a lukewarm boiled solution of sodium chloride, nine parts in a thousand parts of water, preferably distilled water. According to the cases, layers of sterilized gauze soaked in the serum are applied to the wound, or serum-soaked strips of gauze are introduced into fistulus tracts and deep cavities. Undiluted serum may be injected into the wound channels, if preferred. A dry protective dressing is then applied. The serum dressings are removed according to requirements in a

given case, usually in the morning and at night. Prolonged use of the polyvalent serum in form of wound dressings involves no danger of anaphylaxis or other complications.

*Polyvalent Serum in Hypodermic and Intravenous Injections.*—Although the use of polyvalent serum in wound dressings is safe in all cases, injections may give rise to symptoms of anaphylaxis in patients who have previously received a preventive injection of antitetanic serum. As a precautionary measure in such cases, 2 c.c. of the polyvalent serum should first be injected under the skin, guarding against penetration of the needle into a vessel; at the end of eight to ten hours, in the absence of symptoms, an injection of about 20 c.c. may be applied. For the intravenous use of the serum, the patient is prepared by a preliminary very slow injection of ten drops of diluted serum, 1 part, in physiological solution, 10 parts. At the end of a quarter of an hour the serum is injected very slowly in progressive fractional doses (two drops, one-quarter c.c., one-half c.c., one c.c., two c.c.), carefully observing the patient's reaction and injecting ether, if necessary.

*Precautions.*—Serum flasks which have been opened should be utilized at once.

*Preparation of Autopyovaccine*, of Weinberg and Séguin (Séances et Mém. d. l. Soc. de Biol., Vol. 79, 1916, p. 2).—The required time is only one to two hours. A small quantity of pus or serum from the wound is placed in contact with Lugol's solution (one-third diluted with distilled water) during ten to thirty minutes, the mixture is then centrifugated, the sediment is freed from its liquid portion, and taken up with a few c.c. of physiological salt solution. Contact with the iodated solution is lengthened (twenty to thirty minutes) when the wounds contain sporulated elements.

Microbes treated in this manner, including the spores, are not only rendered inocuous, but almost invariably destroyed.

The injections often produce a sudden improvement of the general condition and a diminution of the œdema in the wound surroundings. Sixteen wounded soldiers, under the observation of Delbet, including five cases of gas phlegmon and gas gangene, were treated with very beneficial results. The real value of this and other autovaccines remains to be tested on a more extensive scale.

### Donaldson's Method (Introduction of Living Anaërobes)

A method of wound treatment by the introduction of living cultures of a spore-bearing anaërobe of the proteolytic group has been suggested in the last few months by Donaldson and Joyce (Lancet, II, 1917, p. 445). Using the salt pack method, with good results, they made the clinical observation that cases that smell (the odor being one of the most characteristic features of these cases) do well, while those which do not smell make no headway. Bacteriologically, a certain bacillus was found to be apparently constant in the wounds which emit the odor, while it is absent or cannot be recovered from those which do not smell. This bacillus is a spore-bearing anaërobe of a saprophytic nature, and belongs to the proteolytic group of organisms. It acts, apparently in virtue of its proteolytic powers, only on devitalized tissue, and possibly on toxalbumens, and appears to possess no power of attacking healthy structures. Its functions are directed towards the removal not only of the grossly damaged tissue, but it succeeds also in attacking the microscopically damaged structures. As a result, the body forces are freed from the constantly expected menace of septic poisoning, thus allowing them to begin the work of repair. The authors give examples of gunshot-wound cases which had been treated in various ways previously, including the salt pack method, but without success. "These, however, on being sown later with living cultures of the

bacillus, have immediately started to do well, and have ended in rapid recovery."

It is too early to comment upon this new departure, beyond pointing out that it is an added argument in favor of the growing conviction that the presence of devitalized tissue in a wound represents the real danger element of wound-infections.

## CHAPTER II

## WOUNDS AND FRACTURES OF THE SHOULDER

### I. Anatomical Types and Clinical Course

It is sometimes very difficult to be sure that the joint is involved when a missile has traversed the shoulder: the thick muscular covering in powerful men, the diffuse pain, the swelling due to effusion of blood which often is extreme, the frequent coincidence of injury to the lung, especially in soldiers hit in the left shoulder, are factors that may render the diagnosis anything but easy when the bony injury is not extensive. It is well to be forewarned of this, for mistakes are common.

It should be borne in mind that if a radiograph is not obtainable it is better to diagnose a fracture that does not exist, than to overlook a joint injury which will manifest itself all of a sudden by grave complications. I lay special stress upon this point, for I have twice received in my ambulance at the front men hit in the lung for immediate incision of the pleura in whom the septic conditions were really entirely due to an arthritis of the shoulder. Immediate exploratory incision showed that the bullet before entering the thorax had ground fragments of clothing into the head of the humerus, and that this was the cause of the infection.

Four prominent anatomical types are observed in injuries of the shoulder.

*The crush-fracture* (*fracture parcellaire*).—This is a

crushing of the trabeculae of the cancellous tissue after fracture of the cartilage, or the compact shell of the head, with or without a shrapnel ball, splinter of shell or grenade *in situ.*

*A fracture limited to the head.*—A furrow or groove at the level of the anatomical neck, or a tunnel through the cancellous tissue, with or without radiating fissures, but without detachment of the head. This is more often the result of long-range bullets, and in these cases complications do not usually develop.

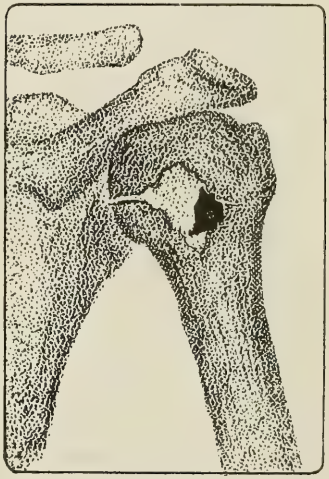


FIG. 10.—The projectile is embedded in the head of the humerus surrounded by a progressive osteitis. The radiograph was taken fifteen days after the injury. Subsequent removal with localised subcartilaginous clearing out of the head of the bone has produced a good result, but the movements of the joint are limited by adhesions. An operation immediately after the injury would have given a better restoration of function.

*Complete separation of the head* along a line which may correspond to the line of the epiphysial cartilage, which is still present in young soldiers, since it rarely disappears before twenty-two years of age.

*Complete destruction of the upper end of the humerus*, a very frequent injury, indeed the most frequent of all, produced either by a short-range bullet or by a splinter of shell or grenade. In these cases it is not unusual to find the whole of the upper end of the bone smashed to atoms. The bone-dust and splinters are driven into the muscles which are crushed, lacerated, and contused, and in a few hours become the seat of formidable septic phenomena which develop with great rapidity. These injuries may exist alone or in

conjunction with other fractures of adjacent parts, such as fracture of the coraco-acromial arch, of the glenoid cavity, and of the scapula.

*What is the course of these different types?*

*The crush-fractures*, with the projectile remaining in the head of the bone, are sometimes mild in their course when they are due to a bullet or a shrapnel ball, but one often sees progressive osteitis occur around the projectile, or œdema of the shoulder signifying deep infection, and sometimes a late suppurative arthritis. Complications are the rule if the injury is due to a shell-splinter.

*The crush-fractures and the fractures limited to the head* may run an aseptic course and behave like simple fractures when they are produced by long-range bullets which have perforated the shoulder like a trocar, through punctiform skin openings.

But in all the other cases and invariably when the wounds are made by splinters of shell or grenade, however small the wound of entry may be, osteo-articular infection is the rule; one should always be on the look-out for it because of its great frequency. The few cases which progress without grave symptoms are very similar at first to those which are followed by gas gangrene.

Often, especially when there is destruction of the head of the bone by a bullet or shell-splinter, infection follows with extreme rapidity; in a few hours the temperature reaches 40° C. (104° F.); the general condition becomes grave, the complexion waxy, the lips pale and the cheeks flushed; the shoulder is swollen and globular; the signs are those of an acute diffuse cellulitis; the least movement makes the patient cry out. The same evening or on the next day there is gas in the tissues, the appearance of the patient is that of a man profoundly toxic, and, unless active intervention is practised, death quickly ensues.

This is the usual course of about a third of the cases

at the front unless immediate action is taken. More frequently the symptoms are less acute, the infection is slower; the shoulder slowly swells up, the flat surfaces are effaced, hollows disappear, the whole region is painful, and from the swollen lips of the wounds there exudes a fœtid sero-purulent discharge. Sinuses occur on all sides, but especially in front along the biceps, and in the axilla. Unless appropriate treatment of the bony lesion is carried out, the patient wastes, becomes cachectic, and slowly dies of amyloid degeneration, if disarticulation is not performed. A small number of cases get well spontaneously with ankylosis and sinuses.

Results such as these of fractures of the shoulder left to themselves, can be avoided; they ought no longer to be seen. A wound of the shoulder correctly treated from the start ought not to suppurate, and should get well quickly.

### II. Primary Therapeutic Indications

1. Simple Immobilisation.—This is only suited to very mild cases, that is to say to bullet wounds with punctiform openings. These wounds do not suppurate and the cases behave like simple fractures. The only indication in them is to apply an aseptic dressing and strictly immobilise the joint in a plaster casing made in the manner described farther on. If the cases are numerous, one would apply a wire splint suspended from the top by means of a sling over the opposite shoulder. Immobilisation should be kept up for three weeks, so that the hæmatoma can be absorbed without injudicious interference, after which some cautious attempts at movement should be made, and the arm placed in a sling. Generally, consolidation is rapid, but ankylosis is the rule. If radiography shows much damage to the bone, it will be well to apply continuous

extension and treat the injury as if it were a fracture of the shaft.

2. Esquillectomy and Sub-periosteal Resection.—A limited bone operation is necessary in all cases of medium severity, that is to say in the more or less extensive fractures of the head of the humerus; esquillectomy is suitable for the smallest injuries, resection for the others, which form the majority.

Let us take an apparently simple case. A small shell-splinter has traversed the shoulder from before backwards and a fracture is manifest; as yet there is clinically no infection, and the wound is only of a few hours' duration. One is tempted to say, "No intervention, simple immobilisation: if symptoms of infection appear, there will always be time to make an incision." This easy-going optimism appears all the more justified because at the shoulder a flail joint, due to loss of bone is very crippling, especially if the muscles are destroyed: ankylosis is better than a flail-arm, and one can understand the desire to wait until one is forced to intervene. No one has the right to do this: the risks of waiting are too great to allow one to expose the patient to them by speculating upon the chances of a natural cure. The uncertainty of delay, the impossibility of knowing whether urgent evacuation will become necessary, the ever-present menace of infective complications whose severity it is beyond one's power to foresee, our absolute ignorance of what the missile has implanted in its passage through the bone or the joint, taken together, impose upon us the duty of making an early intervention in all cases except the punctiform bullet wound, in order to expose the damaged bone and clean it.

The advantages of this method of procedure are the following:

*Complete suppression of severe primary septic phenomena* (gas gangrene, septicæmia, acute articular osteitis), which carry off a large number of patients,

By practising primary clearing of the bone lesion by esquillectomy or resection, I have not lost a single case of injury to the shoulder.

*Avoidance of early secondary disarticulations,* which are numerous in the ambulances when the wounded arrive late, or in which immediate systematic operation is not the rule. Two-thirds of these could have been avoided by primary resection. Personally, I have only done one disarticulation of the shoulder in twenty months of war.

*Progress that is entirely or almost entirely aseptic from the clinical point of view,* without suppuration of the articular lesion, with rapid cure and preservation of the functions of the muscles.

If the operation is correctly done, that is to say rigidly sub-periosteally, if the muscles are sound, if the circumflex is not severed, and if the bony damage is not too extensive, the prognosis as to function is ordinarily good, often excellent, rarely bad. On the other hand, many patients who get well with ankylosis suffer from some degree of osteitis, have sinuses, and are exposed to recurrent attacks of infection. I have lately seen a soldier wounded by a bullet fourteen months ago who recovered with incomplete ankylosis after repeated drainages, and who got a chill and was suddenly seized with a very acute attack of epiphysial osteomyelitis with extensive suppuration on the eve of setting out for a colony where his business interests lay. Systematic abstention from early operative interference entails terrible future risks. That is why we should bear in mind the possible future of our patients, and endeavour to minimise the risk of suppuration in any joint.

*What practical steps should be taken?*

As soon as possible the wound should be explored, the wounds of entry and exit laid open, torn muscular débris clipped away, and particles of clothing and foreign bodies sought for. When this has been done,

the joint is freely exposed and the seat of fracture methodically examined by enlarging the opening made by the projectile.

(*a*) If the fracture is incomplete and the missile is embedded in the bone, the damaged area of bone should be cleared out with a curette and anything removed that appears suspicious. These sub-cartilaginous operations give excellent results. After

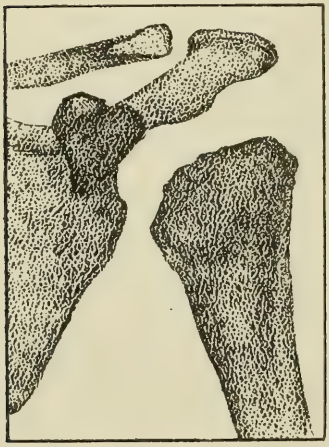


FIG. 11.—Simple fracture of the head of the humerus by shell-splinter. Separation of the head of the bone was treated by early resection by the classical incisions, in spite of the wound of entry being posterior.

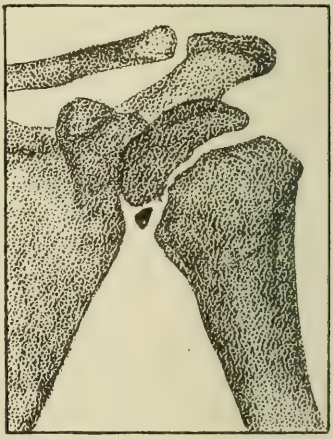


FIG. 12.—Result at the end of two months, when the wound had completely healed without suppuration. The patient has recovered full movement of the joint.

the missile has been removed, nothing further is required than to plug the wound loosely with aseptic gauze.

(*b*) If the fracture is very small and only involves part of the head of the humerus, simple esquillectomy will suffice ; any loose cartilage is removed and the wound is plugged lightly and left open. It goes without saying that all foreign bodies and débris of clothing on the surface of the bone are carefully sought for,

and that any projecting points are chiselled away; no attention need be paid to vertical fissures, which will remain aseptic if the principal area of damage is cleared out. The same line of treatment will be pursued if the head of the bone has been split vertically; the part continuous with the shaft will be left after trimming it up with cutting forceps so as to adapt it to the glenoid cavity.

(*c*) If the injury is more extensive and there is a complete fracture with numerous fragments, and fissures extending into the shaft, it will be necessary to leave the orifice of entrance made by the projectile after cleaning it thoroughly, and to open the joint by the classical incision for resection along the inner border of the deltoid, incise the capsulo-periosteal sheath outside the bicipital groove, and separate the periosteum with the rugine in the direction of the bony injury. If the head is free in the cavity of the joint, it should be removed and the joint cavity cleared of all fragments; if the head of the bone is comminuted, the humerus should be sawn through at the level of the anatomical neck and the fracture a little obliquely downwards, and this will be a very good section if the insertion of the capsule has been carefully preserved. After this has been done, a posterior counter-opening for drainage is made, enlarging the wound made by the projectile if it is conveniently situated, or making a fresh opening in a suitable spot when there is no posterior wound, as will be described later on.

3. Extensive Resection.—At the shoulder the explosive effects of a short-range bullet, or fragment of shell or grenade, are often very marked, and the whole of the upper end of the humerus may be smashed up. The muscular damage is considerable, and the injury to the bone affects both head and shaft, the upper third of the humerus being destroyed and reduced to splinters which are driven into the muscles.

The least delay in operating allows the rapid development of infection.

A good number of these injuries have been successfully treated by disarticulation at the shoulder-joint. On one day in a neighbouring ambulance I saw six disarticulations which had all been performed during the same week for fractures of this kind. Yet whenever the vessels and nerves of the arm are intact one may try to save both life and limb, even to the extent of actually removing the entire upper half of the humerus. This procedure is at present in rather bad odour, because in the early days of the war many inexperienced surgeons performed esquillectomies that were too extensive and perfectly useless, and through ignorance caused terrible mutilations. But the cases under discussion do not come into this category. In them we have to choose between an extensive removal of bone in order to preserve the hand and its movements, and disarticulation at the shoulder: the former operation is, then, one that cannot be too highly recommended. Indeed the opening up of this enormous damaged area stops infective complications, especially if it is immediately followed up by regular sunlight baths; after a longer or shorter period of very localised suppuration, which the sunlight shortens remarkably, repair occurs rapidly and uneventfully, and the patient, if care is taken of his muscles, recovers with a useful flail-arm, a normal hand, and very mobile fingers which are certainly more useful than even the best artificial limb after disarticulation. Doubt has been cast upon the usefulness of this "deossified" limb. But it is none the less certain. In peace-time one was able to study the functional value of cases of total removal of the humerus; the results were so satisfactory that during recent years extensive or total removal of the humerus was advised for neoplasms. "Deossification," therefore, is quite legitimate in military surgery for the very severe cases which are met with there. I per-

sonally have practised it many times, and I was able to show the Société de Chirurgie a patient who had lost more than six inches of the humerus, and further had had a resection of the upper ends of the bones of the forearm done on the same side, and yet enjoyed considerable useful movement. The operation should be done as far as possible with the rugine, with as little periosteal damage as can be managed. One can hardly expect from these measures a bony column sufficiently firm to unite the part which remains with the glenoid cavity, but the muscles are more completely preserved, and their contraction will eventually greatly improve the future condition of the wounded whom we are all so anxious to save.

It is the rule that in cases of fracture where disarticulation appears necessary, but where integrity of the vessels and nerves leads one to hope for a useful hand, the surgeon should do a primary resection without being deterred by the fear of too extensive sacrifice of bone. This method always succeeds in preventing or minimising septic complications.

To sum up, we may say that, putting aside gunshot wounds with punctiform skin openings, one should practise the following primary operations for all wounds of the shoulder:

For crush fractures, removal of fragments and curettage.

For limited fractures, sub-periosteal resection.

For destruction of the upper end of the bone, very extensive resection.

This method will avoid septic complications and disarticulation. But there are certain complicated cases, such as multiple fractures of the shoulder girdle or co-existing wound of the chest, which demand special treatment.

(*a*) *If a fracture of the humerus is complicated by multiple fractures in its vicinity*, such as fracture of the coraco-acromial arch, of the glenoid cavity, and

especially of the scapula (a frequent occurrence), very careful clearing out with sub-periosteal removal of the fragments is more necessary than ever. In cases of this kind I have seen disarticulation performed at the shoulder-joint followed by partial resection of the scapula. It is an over-rated method: esquillectomy is quite sufficient if it is properly performed.

(*b*) *If there are concomitant pulmonary injuries*, which is frequent, the case is difficult: on the one hand the condition of the lungs, the dyspnœa, and the shock contra-indicate even a short anæsthesia, while on the other hand there is the imminent risk of formidable complications.

It is, however, possible to surmount the difficulty: the dyspnœic patient should have some morphine at once and be put to bed wearing a sling which fixes the fractured limb against the thorax. After the lapse of some hours, when the dyspnœa is less and the patient is better, the sling is removed, and after another injection of morphine the scapular wound is laid open freely with scissors, and when thus exposed to the air it is no longer exposed to primary gas gangrene or fulminating sepsis. Without interfering with the deeper structures, the arm is again fastened to the thorax. In this way one can safely wait without causing aggravation of the pulmonary condition. As soon after this as the state of the chest will permit, further surgical intervention will be necessary. These patients bear an anæsthetic fairly well, especially if it is preceded by an injection of morphine.

### III. Operative Technique

1. Means of Access to the Articulation.—Every operation on the shoulder must be dominated by the desire to preserve the attachments and the nerve-supply of the deltoid. Its nerve, the circumflex, emerges from the axilla between the humerus and the

outer edge of the long head of the triceps, runs round the surgical neck which it embraces like a collar in company with the posterior circumflex artery, and approaches the joint as it runs towards the front of the shoulder. On its way it gives off branches which pass vertically into the deltoid muscle, and terminate at its anterior border. The nerve thus runs more or less parallel with the outer border of the acromion, from which it is distant, in an adult of medium height, about 2¼ inches No posterior incisions, therefore, should be made at this level lest they should divide the nerve and thus paralyse the greater part of the muscle. The area of election for an incision is the front of the shoulder, just outside the interval between the deltoid and the pectoralis major, which interval is itself to be avoided because of the cephalic vein.

FIG. 13.—Distribution of the circumflex nerve over the back of the shoulder, showing why posterior incisions should be avoided if possible, to obviate paralysing the deltoid.

In a general way any wound of entry or exit of a missile lying outside the area mentioned above should be looked upon as not available as a route to get access to the head of the bone, but rather as an opening that can be made use of for drainage.

These general principles being laid down, the procedure should be as follows:

(*a*) When there is no posterior wound, an exploratory incision is made at the level of the wound of entry; it should not extend below the limits indicated above. If there is not enough room, it should be extended upwards

to the posterior border of the acromion, from which the insertion of the deltoid should be separated with a rugine for about half an inch or so.

If, after incising the deep fascia and exposing the joint, a limited injury is found that can be dealt with by a superficial esquillectomy and extraction of the missile, this exploratory incision will suffice. If, on the contrary, the bony lesions are extensive, and if there is a comminuted fracture of the head necessitating resection, the classical anterior incision must be made, the posterior opening serving simply as a means of securing the necessary drainage.

FIG. 14.—The best incision for exposure of the shoulder-joint.

(*b*) When there is an irregular wound with smashing up of the head, and in all cases in which resection appears necessary, an anterior incision should be made at once without troubling about the wound of entry.

This incision, beginning half an inch below the clavicle, runs downwards and outwards in the direction of the fibres of the deltoid as far as may be necessary. If there is not enough room above, the insertion of the deltoid into the clavicle can be removed for about an inch. The edges of the incision in the muscle are drawn apart and the articulation is exposed. Even when the capsule is torn, although there may be severe damage to it, it is important to make the incision to the outer side of the tendon of the biceps and parallel to it. This structure can be defined accurately by rotating the humerus a few times.

2. Subcapsulo-periosteal Denudation: Section of the Bone.—From this point onwards the cutting rugine alone ought to be used. If the fragments of the head are too freely movable, they should be fixed with forceps, so that the periosteum can be stripped off, biting into the bony tissue rather than leaving any of the fibrous attachments adherent to it. In this way the insertions of the supra-spinous and teres minor muscles on the outside will be carefully detached, the humerus meanwhile being internally rotated; on the inside the insertion of the subscapularis is similarly treated, the humerus being rotated externally. It is important to strip off the periosteum everywhere, and to tear nothing, so as to preserve as far as possible the capsular periosteum as well as the insertions of the muscles.

*If the missile has struck the upper part of the head of the humerus*, splintering the intra-articular portion, it is enough to clear the joint cavity of all bony fragments and smooth off any projecting points with a chisel, so as to shape the extremity of the humerus to the glenoid cavity.

*If the head of the humerus has been split vertically*, the part that remains attached to the shaft is preserved, and its surface is trimmed with bone forceps, which should be made to remove the articular cartilage as well.

*If the end of the bone has been extensively comminuted*, the whole of the head is removed, leaving only any large fragment of the tuberosity that may be present. If necessary, the saw is applied through the surgical neck. No notice need be taken of fissures running down into the shaft. They repair of themselves when the principal injury has been suitably treated.

*If the upper extremity of the humerus has been entirely destroyed*, it must not be thought that the injury to the bone is too great to admit of cure, and

that disarticulation must be performed. The anterior incision should be enlarged as much as may be needful and the fragments of the head and shaft carefully removed by means of the rugine and followed down as far as necessary. Any very large fragments, embracing one-fourth the circumference of the shaft, should be spared. But in these cases there must not be undue economy of bone in order to save the limb. By removing from five to six inches of humerus, I have succeeded in avoiding disarticulation, even where there were other accompanying fractures, of the inferior maxilla in one case, of the radius, the ulna, and of the skull in another.

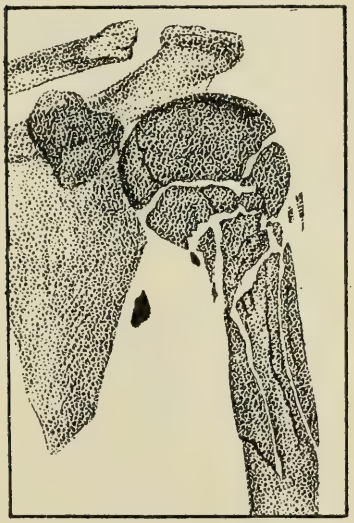


FIG. 15.—Comminuted fracture of the head of the humerus caused by a shell-splinter with extensive destruction of muscular tissue. Removal by the rugine of the head of the bone and many fragments obviated disarticulation and has preserved a useful upper limb. A cure was obtained in two and a half months without any sinus.

*If the fracture of the humerus is complicated by fracture of the body of the scapula*, the method will be the same, and it should not be thought that the injuries are too extensive to admit of conservative treatment. The coraco-acromial fractures should be cleared in the same way as the humerus, but less freely. When the articular cavity is cleared, these injuries run a favourable course ; if the glenoid cavity is broken, complete scapulo-humeral resection should be done by means of a deltoid flap, turning the muscle off its attachment to the acromion.

*When there is a fracture of the body of the shoulder-*

*blade*, the scapular wound should be incised and the fracture treated by an extensive esquillectomy. Unless this is done, severe septic infection may take place in the subscapular fossa and endanger life.

Likewise if the glenoid cavity is broken, free esquillectomy should be performed: sufficient articular support will be obtained if the periosteum is preserved.

Whatever may be the extent of the intervention, every resection of the shoulder and every intra-articular esquillectomy of any importance should be completed by a posterior counter-opening for drainage at the seat of election, that is above the circumflex, utilising if possible one of the wounds made by the missile.

## IV. Post-Operative Treatment

1. Temporary Dressing and Immobilisation.—When posterior drainage has been established, the anterior resection or esquillectomy wound is plugged with aseptic gauze. While an assistant supports the elbow, and holds it slightly away from the body, an absorbent dressing, thicker behind than in front, is applied. Before this is done, care is taken to fix the drainage tube with a pin, and to cut it off very short, so that the pressure of the dressing cannot make the contact unbearable.

Immobilisation can be done in two ways.

(*a*) If the patient remains on the spot and can be followed, especially when the operation on the bone has been important, and when an abundant discharge from the wound is expected, it is only necessary to keep the arm against the side by means of the dressing, the elbow being bent and the hand brought up across the chest. After the limb has been surrounded with wool, it is fastened to the chest by a circular bandage which supports the elbow by means of turns of bandage passing over the sound shoulder. This bandage,

which is similar to that for dislocation of the shoulder, secures perfect immobility when it is well applied, and the patients on whom it is used do not complain. I use it habitually in the early stages of treatment.

(*b*) When it is seen that the dressing will be able to remain in position for several days, and the wound

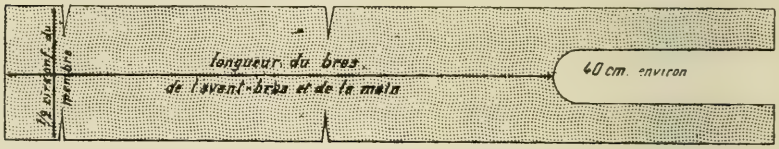



FIG. 16.—Pattern of casing for immobilising the upper limb and particularly the shoulder.

will progress aseptically, or still more, if the patient is liable to unexpected evacuation, a plaster casing should be made in the following manner: The splint is made of a dozen thicknesses of tarlatan the length of the limb—measured from the prominence of the shoulder to the thumb with the elbow flexed—increased by about 16 inches). This is cut so as to obtain :

(1) A covering for the postero-external surfaces of the arm and forearm and the ulnar side of the hand, embracing more than half of the circumference of the arm above, and just half the circumference of the forearm below.

(2) Two bands to pass obliquely across the thorax.

The upper part of the splint will form a shoulder-cap, closely embracing the prominence of the shoulder. To make sure of a perfect fit, the two thoracic bands are crossed over each other before carrying them across to the opposite axilla, so that their overlapping may strengthen the zone of flexion. At the level of the elbow two notches are cut to permit of flexion (fig. 16). For the evacuation of elbow wounds a plaster casing identical with that shown in fig. 41 may be made.

This casing is fixed by means of bandages which go

round the thorax above. If care is taken to put wool in the axilla to keep the humerus in good position, *i.e.* to prevent the tendency to adduction produced by the pectoralis major, this casing will last for many dressings : it is removed at each dressing, and re-applied if the discharges have not robbed it of its firmness.

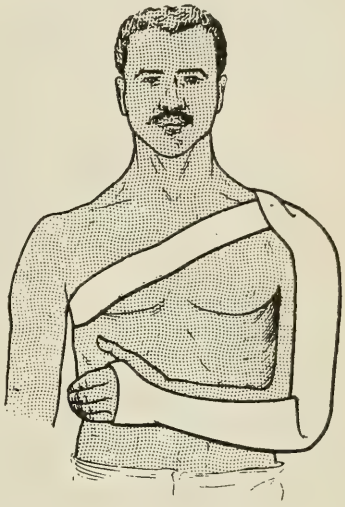


Fig. 17.—The casing applied.

2. Later Dressings and Permanent Immobilisation. — There is every reason to delay the dressing as late as possible : it is well not to change it for three or four days, even if it is very soiled, or longer if possible. Sometimes severe pain makes it necessary to inspect the wound earlier. This pain is often due to the posterior drainage tube, which, being of use only during the first forty-eight hours, can be withdrawn for good or replaced by a smaller one. As soon as the wound is healing well, the dressings can be facilitated by using a plaster apparatus provided with a window or a metal interruption. The extent of the wound ought to decide the choice between these patterns, which are made in the following manner :

(*a*) If the wound is not too extensive and there is little discharge, and if its edges are supple, a " windowed " splint will be made.

To do this, the thorax is covered with a jersey, or a roll of gauze, and a jacket is made by means of plaster bandages. It is not necessary to incorporate any splinting. Two or three bandages $5\frac{1}{2}$ yards long will suffice to cover the thorax with a firm plaster

shield, moulded over the shoulder and both clavicles. When the thickness is considered sufficient, the bandage is carried in figures-of-eight from the shoulder over the upper limb round the axilla, and then down over the arm and forearm as far as the metacarpus. The arm is fixed in a position of abduction, the elbow slightly away from the body, and the forearm flexed midway between pronation and supination, the thumb upward. The upper limb being completely covered in regular turns with three bandages, windows to display the wounds are cut out with a knife, whilst the plaster is drying. The openings should be large enough to prevent the plaster from being soiled, and some dressing should be slipped under their edges to avoid friction ; the casing is also cut away beneath the axilla. This splint should be worn for a month, at the end of which time cicatrisation will generally be complete. A sling may then be substituted and movements commenced.

FIG. 18.—Casing with window.

(*b*) If the wound is very extensive and large openings are called for, a bracketed apparatus should be employed. This will be constructed in accordance with the general rules of immobilisation, that is to say, it will take in the trunk and the elbow. In order that the arm may be well supported, a metal triangle made out of a piece of bent hoop-iron, or some similar

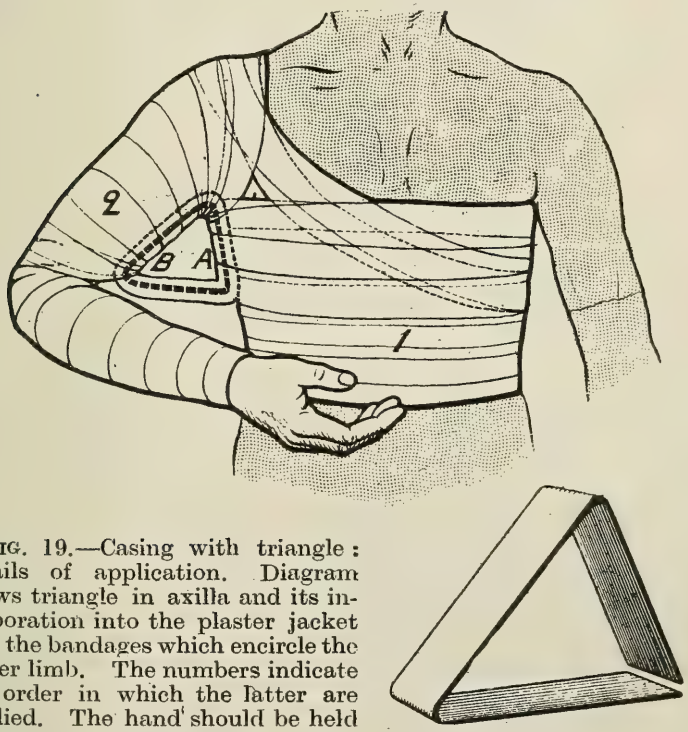



FIG. 19.—Casing with triangle: details of application. Diagram shows triangle in axilla and its incorporation into the plaster jacket and the bandages which encircle the upper limb. The numbers indicate the order in which the latter are applied. The hand should be held so as to support the wrist.

rigid support, is placed in the axilla. Each side of this equilateral triangle will be from 6 to 8 inches in length.

The apparatus will comprise:

(*a*) A plaster jacket covering the wounded shoulder, made with three or four bandages 5½ yards long.

(*b*) A bandage going round the upper limb from the shoulder to the lower border of the metacarpus (three bandages).

(*c*) A triangle made of hoop iron, padded with wool surrounded by a gauze bandage.

(*d*) An interruption of iron wire shaped like a bridge ; the arms of this bracket, whose extremities will be raised a little to prevent it from slipping, take purchase

FIG. 20.—The same casing completed ; a bandage supports the forearm and hand.

above from the cervical side of the coraco-acromial arch, in a line from the shoulder to the nape of the neck ; and below, from the lower part of the arm below the wounds.

The plaster will commence with the corset, in which will be incorporated the thoracic side of the axillary triangle. When that has been well fixed, the bandage will pass over the shoulder in a figure-of-eight round

the axilla and the neck ; then it is carried down the arm, fixing the humeral side of the metal triangle. Then follows envelopment of the elbow and the hand in the position already indicated.

Lastly, the metal interrupting bracket will be placed in position and fixed to the plaster casing by another bandage. All that remains to be done is to cut the plaster bandage away from the area of the wounds and smooth off the edges of the apparatus.

3. MOBILISATION.—This ought not to be commenced

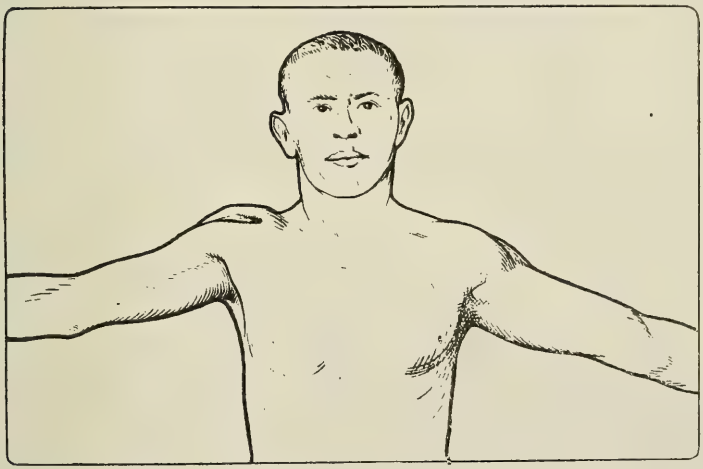


FIG. 21.—Result of primary resection for comminuted fracture of the head of the humerus, after six months. The scar of the anterior incision is distinctly seen on the right shoulder. The arm of the side operated on appears to be raised higher than the other, but by examining the line of the shoulder it is easy to realise that the shoulder-blade takes part in the movement.

too early. It is necessary indeed to wait until the humerus is sufficiently fixed against the glenoid cavity, before seeking to get even slight movement. Unless this precaution is observed, the humeral extremity may be dislocated by the adductor muscles below and in front of the coracoid process, and the result will be deplorable.

If resection has been limited to the head, no move-

ments should be commenced for a month. In case of more considerable loss of bone, a longer period is required ; but as soon as cicatrisation is advanced a little the muscles should be either massaged or electrified. Exposure to the sun is one of the best agents for the preservation of muscles. Before any attempt is made at passive movement, voluntary contraction of the muscles should be promoted with the limb still fixed. Elevation and rotation should be the first movements attended to. Abduction, which is the most useful movement, is the most difficult to obtain. That is due principally to injury to the deltoid. Out of ten patients, I have only obtained it satisfactorily in two.

As a general rule, and contrary to what happens in the elbow, undue laxity of the joint is to be feared, rather than ankylosis.

### V. Evacuation of Patients with Shoulder Wounds

With the exception of mere tracks with punctiform openings, all wounds of the shoulder ought to be explored as soon as possible. None ought to be considered as primarily mild.

Removal to the base, without a clearing operation, ought not to be practised unless there is considerable over-crowding, when it becomes clear that the patient will be more quickly operated upon if he is moved than if he remains *in situ*. In this case the patient ought always to be detained in the first surgical line (*relai*) he comes to. He should never travel for more than twenty-four hours.

*What is the most favourable time for evacuation of a patient who has undergone esquillectomy or resection?* It is at the end of a week, if the patient cannot be kept longer. Simple esquillectomies can travel after three or four days, with their injured limb immobilised in a plaster casing designed for that purpose. After

extensive operations for the removal of bone, as for destruction of the upper half of the humerus, it is advantageous to retain the patient as long as possible, fifteen days at least.

*Apparatus for transport.*—The plaster splint described above (see fig. 18) is generally sufficient. A plaster casing of the Hennequin type may also be used. The elbow should be slightly adducted without being in contact with the wall of the thorax, the forearm flexed, and the axillary pad in place. This apparatus should be removed on his arrival. The journey should not exceed forty-eight hours.

### VI. Treatment of Patients seen late or after Evacuation

1. A Patient, who has been lying out for some time, arrives at the Ambulance at the end of 24 to 36 Hours.—There are all the signs of a commencing suppurative arthritis, or of a diffuse phlegmonous inflammation of the shoulder, often gaseous. The wound is sloughing and looks foul.

The sloughing edges should be immediately excised. Sub-periosteal removal of all the fragments that are free and those that are adherent and likely to interfere with drainage should be done at once through an anterior incision. It is really an extensive resection, atypical, like the bone section, having for its object the free exposure of the seat of the articular fracture. If the fracture is incomplete, immediate resection of the head of the humerus should be done.

If the humerus is smashed up and septic, subperiosteal removal of the bone, described above, will be the operation of choice and will generally check the infection ; if it persists, however, especially in a case of comminuted fracture, or if at the outset the gravity of the general condition makes one doubtful, disarticulation at the shoulder-joint should be done without hesitation.

2. A Patient correctly operated upon at the Front arrives at the Base in good condition.—(*a*) A patient who has had early arthrotomy with removal of all foreign bodies for parietal fracture, gets well rapidly. In three weeks fixation should be abandoned, and gentle movement commenced. Treatment by mechanical movement is expressly contra-indicated. As soon as active movements can be performed, the patient himself will do all his own movement.

(*b*) In the case of a patient who has undergone arthrotomy for a splintered fracture, and is doing well, it is necessary to promote ankylosis by strict immobility. The limb is very slightly abducted, the elbow just away from the body, and no heed should be taken of loss of movement, which is inevitable.

(*c*) A patient who has had resection performed ought to be treated according to the indications given above.

3. A Wounded man arrives without having been operated upon, and without any symptoms of serious infection.—Suppose a patient arrives on the third day ; one confines one's energies to enforcing strict immobility by means of a plaster splint, made as described above. Some days later, aided by radiographs, a search can be made for missiles, if there be any, or dead fragments of bone. These cases get well, but often with ankylosis and sinuses.

4. The Operative Treatment has been carried out late, or early Treatment has been insufficient.—The patient arrives in a septic condition with free suppuration.

(*a*) An arthrotomy and esquillectomy have been performed, but the radiograph shows missiles left behind or fragments of bone in a fair way to necrosis. After forty-eight hours of observation and rest, whatever the date of the injury, it will be necessary to complete the first operation and to remove missiles and fragments, carefully sparing all periosteal remains, and excising dead tissues, generally fragments of an

aponeurosis or tendons. Even should the short head of the biceps be concerned, it should be cut away, for a tendon does not recover, and takes a long time to come away spontaneously. If the bony lesions are extensive, resection of the head of the humerus, which is the operation of choice, will be done without hesitation.

(*b*) The injury to the bone has not been touched. There is suppurative arthritis starting from a septic centre in the bone ; the best treatment is resection of the humeral head. Arthrotomies do not drain so well, nor do they allow the cause to be reached. On the other hand, late resections, if they are not too late, often give very good results ; the recovery of function is often better than with primary resections : if one were sure of being always just in time, the general indication would be to wait. At least that is the accepted opinion. But it rests on no precise reason : periosteal regrowth occurs quite as well in a primary as in a secondary resection. In short, the function of the new joint depends above all on two factors : the conditions of the muscles, and the extent of the bony loss. Whatever may come of the argument, one will resect with hope of a good functional result.

If there are purulent sinuses round the joint, notably behind and internally, resection, combined with counter-openings and complete cleaning out of dead fragments, will almost always enable one to avoid disarticulation. That will, however, sometimes be necessary in consequence of the gravity of the general condition, especially if scapular injuries co-exist.

5. THE PATIENT ARRIVES WITH HIS WOUNDS ALMOST HEALED.—(*a*) A sinus persists. Generally this is at the antero-internal part, quite near the axilla—at least I have always seen it there. After radiography the dead bony fragment, or the missile which keeps up the sinus, is sought for, even by doing a sub-cartilaginous scraping out of the spongy tissue of the

head of the bone. This curettage generally ensures a complete recovery, but the wound must be kept freely open, and no attempt must be made to obliterate the cavity by an antiseptic paste, which would certainly be extruded. Sunlight benefits these old bone cases marvellously.

(*b*) The limb is flail-like from want of bony growth. One must distinguish between two types of this condition: limbs which are active though flail-like, and those which are absolutely useless. In those which retain some activity, the muscles are still in a good condition, a correctly performed operation has made the best of them, has saved their nerve supply and maintained their attachment to the periosteal sheath. They preserve their power of contraction, are able to raise the lower end of the humerus with some strength, and thus permit useful movements. In these cases one is tempted to think of bone-grafting. At the present time the operation seems inadvisable and not likely to succeed; the graft would be liable to be displaced, if not absorbed. In a case of this kind in a patient, two-thirds of whose humerus I had resected as well as the ends of the two bones of the forearm at the elbow, a supporting case fitting on to the shoulder has permitted him to use the limb.

In those arms which are flail-like and quite useless, where there are no longer any muscles, suspension must be resorted to by means of an apparatus encircling the trunk and shoulder, with a firm casing enclosing the arm, and giving a solid point of support for the movements of the elbow and the hand. (See fig. 97.)

## CHAPTER III

## WOUNDS AND FRACTURES OF THE ELBOW

### I. Anatomical Types and Clinical Course

EVERY wound in the region of the elbow, even if it extends to the bone, is not necessarily a wound of the joint. Projectiles often chip the surface of one of the bones, without, strictly speaking, penetrating the joint. These wounds, which may be called parietal or para-articular, generally run a very simple course after a suitable incision has been made for the removal of the foreign body and any dead organic débris. Scarcely any limitation of the movements of the elbow is left when they heal. I have seen a dozen cases like this, but it is not necessary to take them into account in speaking of wounds of the joint, and they will not be considered further here.

One only really considers as fractures of the elbow injuries to one at least of the three bone ends inside the synovial membrane.

Theoretically the elbow can be traversed through and through without the bone being damaged, but in practice this very rarely happens. As a general rule, every clean perforating bullet wound of the elbow, however simple it may appear and whatever be its direction, is accompanied by injury to both bone and cartilage, even when radiography shows nothing; when it does show anything, there is always more damage than is apparent.

One bone only may be struck, but that is excep-

tional ; out of thirty-six cases, verified by operation, I have only observed this three times. More often, the fracture implicates two bones ; when the principal injuries are those of the radius or the ulna, there will be extensive damage to the corresponding or opposite part of the humerus, and vice versa. Similarly, the two upper articular ends of the bones of the forearm may be broken simultaneously. Besides, it is easy to understand that all possible combinations may occur, according to the varying path of the missile and the different positions of the arm and forearm. It only matters to remember that *there is always more damage than appears from the symptoms*, and that the fractures of the epiphyses are often prolonged by fissures far down the shaft.

FIG. 22.—Fracture of the elbow by bullet with punctiform skin wounds. Aseptic course in spite of extensive bony injuries. Recovery by simple immobilisation for one and a half months, with limitation of movement ; flexion up to 90 degrees, extension normal. Patient seen in consultation to consider the advisability of further resection, which has been rejected as useless.

In these fractures, which sometimes are very little comminuted, as is especially the case in the humerus, the displacement is usually not considerable. I have always seen the olecranon but slightly displaced, and simply bent forwards and drawn up to the level of the cavity which normally receives it. The head

of the radius remains adherent to the tendon of the biceps by its periosteum. The coronoid process is generally drawn forwards. But all these structures are often unrecognisable, being reduced to small splinters which remain either in the region to which they belong, or are scattered somewhere about the torn-up articular cavity. The missile, too, is close by, but in its course it has often caused fragments of clothing to adhere to the bony points, whence the frequency of infection.

Perhaps the most frequent type is complete destruction of the elbow in which two and sometimes all three articular ends are demolished ; there only remains a sort of bony mess in place of the joint, with splinters and osteo-cartilaginous fragments more or less widely scattered about.

What becomes of these different injuries if they are left untreated during the first few days ?

The surgeon at the front has to distinguish three categories :

Bullet wounds with punctiform openings.

Wounds, blind or otherwise small or of moderate size, made by splinters of shell or grenade.

Large wounds made by short-range bullets, or by large pieces of shell, with great loss of the soft parts and smashing up of the elbow.

(*a*) The fractures caused by bullets with small punctiform skin openings are the mildest ; they usually heal without sepsis, if the limb is suitably immobilised. It must be remembered that, in these cases, it is not the extent of the bony injury but the dimensions of the skin wound which determines the gravity of the case. With a small fracture and a large wound of exit, sepsis is certain. On the other hand, an aseptic course is possible when there is great destruction and the wound is very small. This is not because the infection is introduced from without inwards by the cutaneous wound, but because the

bullet which gives rise to small skin-openings is really one fired from a distance, hitting the body point foremost, and not generally carrying anything with it. It is the famous "humane bullet"; whilst the bullet which produces explosive effects is deformed, has ricochetted or is wobbling, and carries with it débris of clothing and leaves behind it all kinds of infective organisms. The wound it produces has the same elements of gravity as one caused by a shell-splinter, and no distinctions as to the variety of the projectile need be made.

(*b*) In the fractures with skin wounds of small or moderate dimensions apparently of a mild type and caused by splinters of shell or grenade, it is almost necessary to reverse the formula : a small blind wound is more formidable than a large open one. These are generally cases with small skin wounds but much deep-seated damage which is shut off from the air, and is therefore under favourable conditions for the rapid development of septic gangrene. When a wound is wide open, these very acute symptoms are less often observed ; ordinarily an acute arthritis occurs with profuse suppuration and discharge of sloughs and necrosed bone ; the arm becomes enormously swollen ; purulent sinuses call for multiple incisions and repeated removals of bony fragments. After many alarms and several operations, the patient recovers with ankylosis and with or without, more often with, sinuses.

Even if cicatrisation is complete, it does not do to think that everything is well ; in about half the cases there are sequestra in the ankylosed bones, or granulation tissue containing spicules of bone which has all the appearance of tuberculous tissue. It is, however, really only septic, and bacteriological examination shows staphylococci in large numbers. They may disappear gradually, but for a long time this latent infection will be dangerous : it explains the unexpected recurrences of infection, the painful attacks of lymphangitis on the occasion of a chill or of a blow on the

elbow, and in many cases a decided decline in the general health, inexplicable on any other grounds.

Out of twelve resections of the elbow which I have performed for ankylosis after war-wounds, I have found conditions of this kind in seven. In the other five cases the ankylosis had ensued in the ordinary course, and there had been no septic relapses. But in two cases it had only been obtained after many operations that had left the skin adherent to the muscles which were atrophied, fibrous in character, and with much diminished functional power: in consequence of pain, abundant suppuration, and repeated dressings, the position of the limb had been badly overlooked, and after eleven months of painful treatment, a vicious ankylosis necessitated resection for the deformity, which the muscular insufficiency would have almost contra-indicated.

(*c*) In extensive crushing of the elbow by shell-splinters or the explosive effects of bullets, one may see the very rapid development of a septicæmia which ends rapidly in death, or may meet the progressive aggravation of local septic phenomena which calls for amputation, if the life of the patient is to be saved.

The preceding statements can be reduced to the following formulæ:

Bullet wound with punctiform openings = simple development, whatever the type of fracture.

Bullet wound with explosive effects = rapid and fatal sepsis.

Small wound by shell-splinter with fracture of varying extent = gas gangrene or rapidly progressing sepsis in two out of every three cases.

Large wound by shell-splinter = serious sepsis and septicæmia of a more or less rapid type.

To sum up, except in bullet wounds with punctiform openings, sepsis is certain; often it is grave. Therefore, as it is impossible to foresee what the septic

developments will be, it is better in all cases to do a primary operation for prophylaxis and disinfection, as early as the circumstances permit, so as to render the condition aseptic at once.

### II. Primary Therapeutic Indications

We will put aside the bullet wounds with punctiform openings, which simply require an aseptic dressing and immobilisation in a plaster casing for at least three weeks, and only consider, as before, the cases under discussion, viz. all the other wounds of the elbow.

Granted that "armed abstention," either by plaster case or splint, is dangerous, and that a primary prophylactic operation is necessary, three possible operations ought to be considered: arthrotomy with or without esquillectomy, resection, and amputation. To one of these recourse must be had; for one should never be content to push a drainage tube through from the wound of entrance to that of exit, a practice both illusory and useless, and always dangerous owing to the false security to which it gives rise.

1. Arthrotomy.—Arthrotomy for simple exploration, done through an incision, close to the outer border of the olecranon on a level with the posterior wound if there is one and completed by a postero-lateral incision on the inside, is a clearing operation sufficient for slight cases, such as parietal fractures, superficial abrasions of a bone, detachment of a chip of the humerus or ulna, or cancellous crushing due to a missile driven into the bone: all of which are wounds, rather than fractures of bone, strictly speaking. But arthrotomy ought to permit the removal of anything that is detached, and the cutting off of what is irregular or has been bruised. In these conditions, even if there is a radiating fissure, arthrotomy done for purposes of disinfection and extraction of missiles,

when performed quite early, is an excellent operation, which gives the best results; the wounded recover almost complete movement, according to my experience of the three cases in which I have used it.

But when the injuries are more considerable, when an intra-articular fracture is present, and when the necessary measures of disinfection and clearing are required over a wider area, arthrotomy is insufficient,

FIG. 23.—Cancellous fracture of the lower extremity of the humerus, the projectile remaining. Primary operation: removal of the shell-splinter, curetting of the bone, and aseptic dressings.

FIG. 24.—Radiograph of the injury fifteen days after operation. Aseptic course. Recovery with retention of movement.

for it does not go to the root of the trouble. It can, and often does, leave in the joint the remains of clothing, splinters of bone and dead tissues, which are direct predisposing causes of sepsis, gas gangrene, arthritis, and above all acute osteomyelitis, often necessitating amputation, and leading to a fatal issue. As a rule it is advisable to complete an arthrotomy by doing esquillectomy.

This is the operation of choice for most surgeons

in the vast majority of cases: esquillectomy limited and prudent, is the expression they always use, just sufficient to avoid the incidence of acute sepsis. In the favourable cases just described, when the injury is very limited, such as the detachment of the olecranon or of the internal epicondyle, it is capable, when done early, of giving an excellent result.

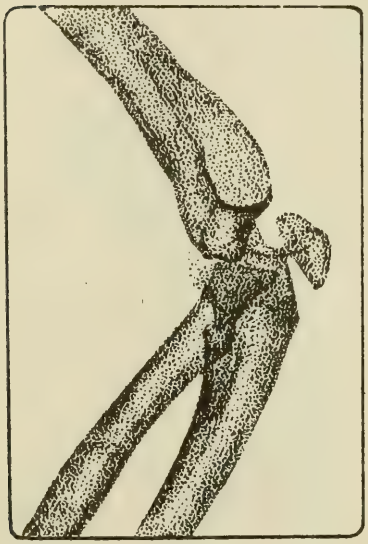


Fig. 25.—Fracture of the olecranon by shell-splinter, treated by simple immobilisation and antiseptic lavage. No operative intervention. Recovery with ankylosis of the elbow. Patient seen in consultation five months after the injury to decide upon the utility of resection, which has been rejected as useless, considering the angle of the ankylosis and the profession of the patient.

But when the damage is more extensive, when a fracture through the epiphysis is concerned, it is almost always insufficient to ensure complete disinfection of the joint. Furthermore, it interferes with the functions of the joint either by ankylosis or by loss of proper movement later. If any infection remains, ankylosis is inevitable, since it causes the cartilage to ulcerate and leaves the inflamed bony surfaces in close contact. As to the loss of the normal movements, this is a necessary consequence of limited unilateral esquillectomy. Ablation of one of the condyles of the humerus destroys the statics of the joint and subsequently interferes with its dynamics: the elbow deviates to one side, and the final result is bad.

In more severe fractures with extensive fissuring, which are in fact the cases of medium gravity, arthro-

tomy and esquillectomy fail to get rid of the septic complications that they are incapable of preventing. In a joint as close-fitting as that of the elbow, simple incision, even when followed by perfect immobility, is less able than in the case of the other joints to prevent or stay the development of acute articular osteitis, which, even in the most favourable cases, tends to become chronic. It is powerless to prevent the necrosis of adherent fragments of bone, whose vitality seemed sufficient at the moment of intervention, but which sepsis has converted into sequestra incarcerated in the ankylosed mass.

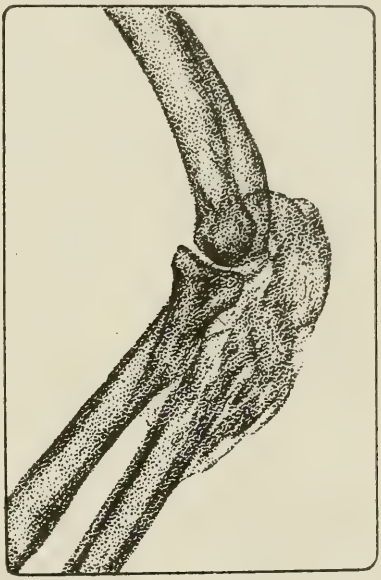


FIG. 26.—Fracture of the olecranon by shell-splinter treated by incision of the soft parts, immobilisation, and antiseptic lavage. Recovery obtained in eight months with ankylosis of the elbow. This case was particularly well suited to primary resection: recovery would have resulted sooner and probably with satisfactory movement. The patient seen in consultation nine months after the injury, before his discharge, submitted to resection which has given a good result, but the power of active movement is limited by induration of the muscles caused by prolonged suppuration and the methods of drainage.

Long after an apparent cure, the elbow remains exposed to relapses of inflammation in the form of intra-articular abscesses and obstinate sinuses, which can only be cured by a late resection. But resection at this stage is a mediocre operation viewed from the standpoint of function. Performed upon chronically inflamed bones, its results are uncertain; I allude to the difficulty

of avoiding ankylosis. On the other hand, even if passive movement can be obtained, there is serious difficulty in regaining satisfactory active movement, which after all is the only useful one. The result usually depends upon the condition of the muscles, which is generally deplorable in the cases under consideration: they are sclerosed and atrophied with indurated and adherent aponeurotic scar tissue, and it is very difficult to restore muscular contractility and anything like the normal suppleness of the tissues.

To sum up, the object sought by means of arthrotomy and esquillectomy can be attained much more easily by primary resection, which is the operation of choice for limited injuries, and which alone is suited for the cases in which there is great destruction of the elbow, and which we are now going to consider.

2. Sub-periosteal Resection.—Immediate resection is, strictly speaking, the type of the clearing operative procedure applicable to all injuries that are not simple parietal fractures or bullet wounds with punctiform openings, and to all cases in which the fracture has upset the mechanism of the joint. Performed in the first few hours or even days after the accident, it permits the removal of organic foreign bodies, fragments of clothing, missiles, and free splinters of bone, together with any other structures that are dead or likely to die. It makes a wound so regular and clean that no sepsis can develop in it; it is really prophylactic against infection, and it banishes the fear of serious complications. Its after-results are very simple, if they are looked after with ordinary care; there is rapid recovery of almost the full range of movement of the joint, after an aseptic healing, and since the patients are men in full physical vigour, with intact muscles, an active new joint is almost always obtained with really excellent functional efficiency.

If the after-care is not what it should be, ankylosis

results; the very result aimed at by the so-called conservative operations of arthrotomy and esquillectomy. Thus, the bad result of a resection is at least equal to the good result of an esquillectomy. Indeed it is generally better, for the ankylosis which is obtained after resection results from fusion of two healthy bones, and therefore the patient is not exposed to the later complications which have been noticed after arthrotomy.

Resection has, however, been much opposed and numerous reproaches have been levelled at it, none of which are justified.

(*a*) To begin with, it is said that resection is not necessary, since injuries of the elbow are mild, and heal easily after arthrotomy. This opinion has only been pronounced hitherto by surgeons at the base who, contrary to what they imagine, have only seen very selected cases. It is well to repeat here that it is a long way from the line of fire to a base hospital, and at these latter only those patients arrive who have been able to stand at least two or three days' journey without developing serious infective complications. Between the wounded in the front line and those who reach the base there is an enormous difference. Those who talk of the mildness of elbow injuries do not realise the number of amputations that these injuries necessitate at the front, especially when resection is not boldly put into practice. And even these figures would only give an inexact impression, for it would not include deaths. It is not sufficiently realised that two-thirds of the injuries to the elbow caused by shell-splinters or the explosive effects of bullets are dangerous to life. Delay in freely clearing out the wound is heavily paid for. Gas gangrene, acute sepsis, arthritis and articular osteitis, lead to early secondary amputation, which the supporters of the supposed mildness of elbow injuries do not bear in mind, probably because they are not

aware of it : nevertheless this fact has to be reckoned with. At almost every medical board at which we see cases that have had amputation of the arm, there are one or two which have been done for fractures involving the elbow-joint. The case-sheet reads : "Gas gangrene, or septicæmia, occurring at the end of three or four days." That is the condition, but primarily it arose from a fracture of the joint, and resection would certainly have avoided both the complication and the amputation.

(*b*) It is also said that esquillectomy is generally sufficient, and that it is a less wasteful operation than resection. It is perfectly true that it is sufficient when the fracture is limited in extent and confined to a single bone. But the avoidance of sepsis at a small cost does not constitute economy. The economy we require is not so much concerned with the bone as with the function of the joint. Now, ablation of a condyle of the humerus, or of a part of the ulna, certainly gives a deplorable functional result. The forearm is in bad position and either varus or valgus occurs. The only way of procuring a good functional result with certainty in this kind of case is to perform a typical resection. I will return to this point later. When two bones are fractured, esquillectomy is only apparently economical. It sacrifices less in width, but just as much in length ; and it is this latter point alone which is important from the point of view of the function of the joint.

(*c*) It is also objected that resection of the elbow is more difficult than arthrotomy, and since war operations are performed by surgeons who have no great experience of bone surgery, they should preferably be simple.

I confess that I cannot understand this reasoning. There are not two kinds of surgery, that of the ignorant practitioner and that of the experienced : the latter alone ought to be the operators at the front. It is

easier to perform a resection at the elbow than to do a laparotomy or tie some large vessel. *The surgeon engaged in the difficult surgery at the front ought to be capable of doing a sub-periosteal resection of the elbow ;* if not, how, I ask, can he perform his daily tasks ? It is his right and his duty to do the operation which appears best from the point of view of the preservation of life and recovery of function.

(*d*) It is further stated that in times of stress it is impossible to supervise the post-operative stages of a resection, and that this is vital. As a matter of fact a resection of the elbow is much more easy to look after than an esquillectomy, which is always liable to the onset of infection. A resection runs an aseptic course, and as a general rule there is no need for further operation, while arthrotomies which suppurate frequently require fresh incisions and always call for daily dressings. In a front-line ambulance a case of resection gives much less anxiety than an arthrotomy. And later on, when the time comes for daily movements, it is very easy to spare two or three minutes daily to perform them. I have always found time to do so while in charge of a large ambulance at the front ; at a base hospital it is simply a matter of willingness to do it, and of organisation.

(*e*) Another objection is that resection is not economical, because it leads to the removal of fragments, which might have been preserved by a waiting policy, and the preservation of which would have diminished the loss of substance.

To me this appears ridiculous. A properly performed resection does not mean a final loss of bone ; if it leads to large sacrifices, it is because the damage is excessive. I do not understand why a T-shaped fracture of the humerus with injury to one of the bones of the forearm, which is a frequent condition, should necessitate too extended a resection. Out of eighteen cases of primary resection, I have never been led to

remove more than was necessary. The whole point is to know if the operation will give a good functional result. Then, if it is correctly performed, that is, strictly sub-periosteally, and if the after-treatment is efficient, it always leads to a satisfactory recovery of function. There is no need to quibble with words: when a fracture of the epiphysis is in question, the most economical operation is a typical resection and not esquillectomy; because the former, by sacrificing more in width, but not in length, is definitely much more preservative of function. When there has been extensive destruction of shaft and epiphysis it is more economical than any other operation, because it will save the limb, its functions, and, sometimes, life itself. In eighteen primary resections I am convinced that I have avoided at least four if not six amputations of the arm and one disarticulation at the shoulder. Thanks to primary resection at the front, I have not amputated once for fracture of the elbow,

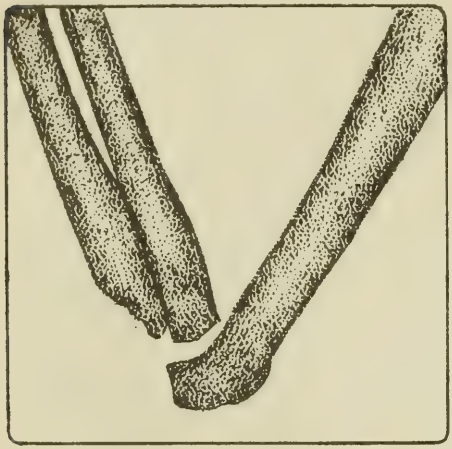


FIG. 27.—Result of primary resection for explosive destruction of the humerus and ulna by shell-splinter. No feverish symptoms. Complete cicatrisation in thirty-five days; perfect restoration of function; complete active extension; flexion, pronation, and supination normal. The patient can carry 15 kilos with the arm raised and can pull 150 kilos with the hand of the injured side. Radiograph taken at the end of eight months; the regularity of the contour of the bones is noticeable. Compare this figure with figs. 7, 8, and 9, which relate to the same case: there is no excessive periosteal bony new growth, as in the secondary or later cases of resection shown in figs. 33 and 47.

and I have not lost a single case. I think, therefore, that I have a right to say that resection is an economical operation.

(*f*) The most important objection is that resection gives bad functional results, because it leads to a flail-limb, which is of much less value than an ankylosed joint. Ankylosis in good position is undoubtedly more useful than a flail-limb. But even the latter with a normal hand is more useful than the finest artificial limb; moreover, it must be admitted that a resection that has called for enough loss of tissue to cause a flail-elbow in all probability saved the limb from amputation. In an operation such as resection of the elbow bad results can only be due to one of three causes: too great sacrifice of bone, necessitated by the extent of the injury (more than $2\frac{1}{2}$ inches of the bones forming the joint), bad operative technique, or faulty after-treatment; of these the two last points are the most important.

FIG. 28.—The same patient as fig. 27. Radiograph of extension in profile: it is noticeable that the forearm is flexed on the front of the lower extremity of the humerus.

Ollier obtained satisfactory recovery of function in patients from whom he removed four inches of the bone, and, like others, I have personally seen similar cases. It can be affirmed, then, that if the results are bad, if flail-limbs are found at the base hospitals, one of two things has happened. Either the operator has been confronted with considerable injuries, in which case he has been well-advised in performing resection, since the operation has in spite of all been conservative; or the injuries were limited but the

technique was bad, in which case the fault is not that of the operation, but of the operator himself, or the surgeon who directed the after-treatment. These last factors, bad technique and bad supervision of the after-treatment, are undoubtedly the most frequent causes of failure. Whatever indeed may be the extent of the damage, strictly sub-periosteal operation in a young man with powerful muscles ought

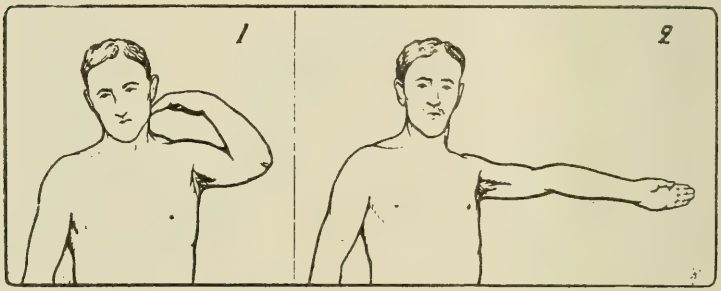



FIG. 29.—Functional result obtained by primary resection of the elbow: photograph taken six months after the injury. The patient has been shown to the Société de Chirurgie. The radiographs 7, 8, 9, 27, and 28 relate to this case.

always to give a satisfactory result, and ought not to end in a flail-joint. This flail-elbow, without the least power of movement, is primarily due to complete muscular insufficiency. When a primary resection is performed, the muscles are vigorous and strong, nothing has atrophied them; when they contract, they bring the newly formed articular surfaces into close contact with one another; playing the rôle of ligaments they articulate the new joint, so to speak, and allow it to work freely and with precision, even if the resection has been an extensive one. Among the eighteen patients upon whom I have done early resection, a large proportion have had considerable amounts of bone removed; none have got a powerless arm; and in all of them, thanks to their muscles, the active movements of the new joint have been good.

One of them, after losing four inches of bone following destruction of the elbow (figs. 30 and 31), can carry more than 10 kilos (20 lb.) with his arm extended; another draws a hand-cart loaded with 150 kilos with the hand of the resected limb. It is interesting to

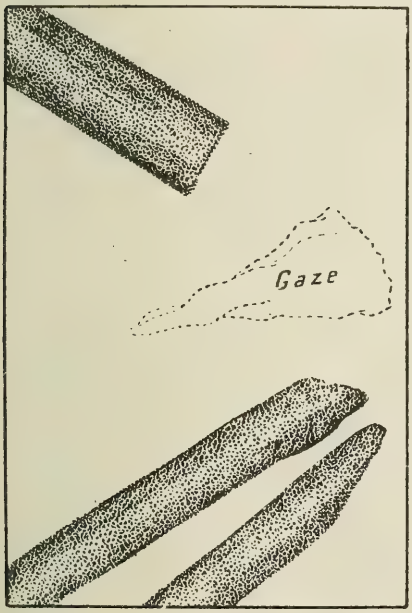



FIG. 30.—Early secondary resection (fifth day) for explosive destruction of the elbow. The splinters having been removed subperiosteally, the end of the shaft of the humerus has been cut straight through with the saw. Radiograph taken twenty days after operation. Complete recovery in sixty-five days after the operation.

FIG. 31.—Radiograph of the same elbow three months after resection, showing the periosteal new formation on the bony extremities. After a year, the patient, in spite of the extensive loss of substance, has a perfect restoration of flexion, extension, pronation, and supination.

note that this man was forty-two years of age when the resection was done, which proves that, from the point of view of recovery of functional power, age is not so important as is imagined. In consequence of what I have seen, I think that the flail-elbow is due to a faulty technique, or to an absolute want of post-

operative attention ; it is met with in consequence of its being forgotten that the patient requires supervision after resection, and should not be left to his own resources during the months that he carries his arm in a splint.

In conclusion, resection is an excellent operation when one knows how to do it, and when one takes the trouble to direct the after-treatment according to the principles of orthopædics and physiology. It should be done at once for all severe fractures, because it is the best method, if not the only one, of preventing or checking infection, and thus avoiding amputation ; and in wounds of moderate gravity, because it is the only way of preventing ankylosis and of preserving the normal mobility of the joint.

Moreover, primary resection is to be preferred, because it does away with infection, which would injuriously affect the progressive regeneration of bone, and because it permits of complete muscular integrity, which ensures a good functional result. After a primary resection, the extremities of the bones are restored with regular, smooth, and clean outlines and mobility is much more easily obtained than after secondary resection in which the periosteum, inflamed and feeble, proliferates so wildly that the post-operative treatment becomes extremely difficult.

The physiology of the joint corresponds with the anatomical condition, and this can be studied by radiography. I have examined a dozen resections under the screen : the play of the joints resulting from aseptic resection is infinitely more supple, more varied and delicate, than it is in those in which resection is done when sepsis is present. The gliding of the bony surfaces is softer and more regular and is effected in one of three ways : sometimes the extremities of the bones of the forearm move in the normal plane, end to end with the humerus (figs. 30 and 31) ; sometimes they pass in front of the lower extremity of the

humerus, which is hollowed out to form a cup like a reversed olecranon fossa (figs. 27, 28); and at other times the bones of the forearm slide a little backwards, and when flexion occurs are almost in contact with the posterior surface of the humerus. With each of these types, of which the two former are the most frequent, the functional appearance is equally satisfactory. Briefly, the radioscopic study of new joints at the elbow demonstrates that after a correct and early operation, the physiological restoration of the joint can be reasonably counted upon; which is one more argument in favour of primary resection.

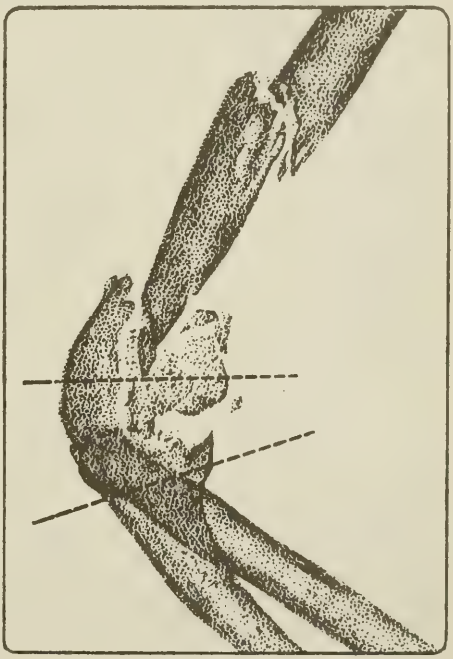


Fig. 32.—Fracture at the middle third of the humerus and severe fracture of the elbow. Resection delayed till the seventy-second day, after union of the fracture of the shaft. Radiograph taken one month after resection.

This operation has only one contra-indication, viz. the presence of a fracture of the shaft of the humerus, or of the bones of the forearm about their centre. In these cases it is better to wait for the consolidation of the fracture and then to perform a secondary resection. This delayed operation has yielded a very good functional result in my hands (figs. 32, 33).

3. Amputation.—There is no indication for primary

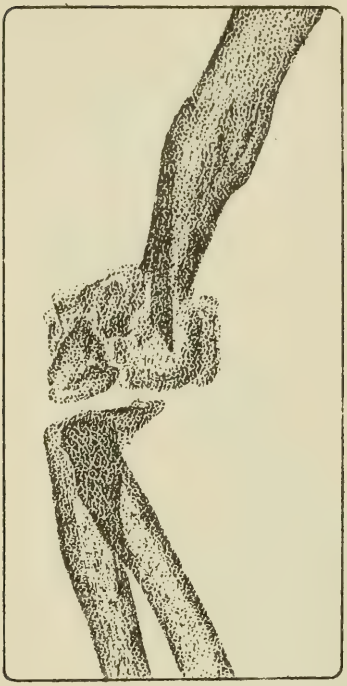


FIG. 33.—The same patient as in fig. 32 : result of a delayed resection. Radiograph at the second month. The fracture of the shaft is united; there is a mass of new bone at the epiphysis; the functional result is good; but there is some difficulty in obtaining satisfactory flexion because of the bony mass at the front of the joint. However, three months after resection active flexion reached 90 degrees, and extension is complete, but pronation and supination are slightly limited.

amputation in fractures of the elbow when the vessels and nerves are not severed, extensive resection being sufficient even in the most complex fractures. Neither is it indicated as a secondary measure, early resection preventing all the complications which might make it necessary.

The indications for operation in fractures of the elbow can be summed up as follows :

Ablation and immobilisation in plaster for punctiform bullet wounds. Limited arthrotomy and esquillectomy for parietal fractures and cases of cancellous crushing by a missile embedded in the bone. Primary resection for all fractures into the joint, and for all bony injuries due to explosive injuries.

Secondary resection for fractures of the elbow complicated with fracture of the shaft, above or below the articular injury. There is no indication for amputation provided that the vessels and most of the nerves are intact.

### III. Operative Technique

(*a*) ARTHROTOMY ought to be performed by two vertical incisions passing as far as possible, one in the space between the supinator longus and the outer head of the triceps, descending thence towards the base of the olecranon ; the other over the internal condyle. There should be no hesitation to make the incision free, and in case of need to convert it into the incision for resection indicated below. Esquillectomy should be done with the rugine, followed by curetting the cancellous bone, so as to remove all suspicious tissue. The arm should be flexed so as to make the incision gape and give more room. The wound is plugged with aseptic gauze, and the limb carefully immobilised. For the first few days it is put in a well-padded wire splint, moulded to the limb and with the wrist extended and the fingers free.

(*b*) RESECTION ought to be done according to very precise rules, all of which are important, though scarcely mentioned by the treatises on operative surgery. The principal point is to aim at following the classical steps of the operation in every particular. There should be no departure from the regular method in consequence of the existence of wounds, either of entrance or exit. From start to finish the operation should be carried out as if they did not exist. It is needless to apply an Esmarch's bandage, and it is better to arrest bleeding as one goes along.

*The Incision.*—Having tried all sorts of incisions, I advise the angular extero-posterior or bayonet-shaped incision of Ollier, which gives plenty of room and does not divide muscle. The median-posterior and the two lateral incisions gape at the end of the operation and form button-holes ; they are liable to cause retention of the discharges and do not give sufficient drainage. The bayonet-shaped incision commences two inches and a half above the projection of the external

condyle and runs along the postero-external edge of the humerus; thence it is directed obliquely downwards and inwards to the base of the olecranon, where it bends sharply to follow the posterior edge of the ulna for two inches; it does not divide any muscle, and leaves the fibres of the triceps untouched.

*Denudation of the Bones.*—When the incision has reached the bone, the knife is discarded for the sharp rugine, which alone is capable of doing, as it should be done, the first, and, from the point of view of the future, the most important part, of the operation, viz. the denudation of the olecranon and the detachment of the insertion of the triceps. By degrees, keeping close to the bone and actually cutting into the bony tissue, the rugine completely detaches the tendon and the periosteum. The denudation of the internal condyle of the humerus and the liberation of the ulnar nerve are then undertaken; this is neither difficult nor dangerous if the rugine is well under control. The instrument must be kept scrupulously in contact with the bone and the groove between the epicondyle and the olecranon carefully cleared.

FIG. 34.—Bayonet-shaped incisions for access to the elbow-joint.

The rugine will ere this have met with splinters and bony débris, and the operation cannot therefore correspond to any written description. The entire attention should be given to clearing the joint of detached fragments of bone. Nothing need be torn away: each splinter of any size is held with forceps while the rugine strips off its periosteum. After fragments have been removed, the systematic freeing of the extremities of the bones is undertaken: first, on the inner side, until the tip of the epitrochlea has been cleared well down on to the ulna, detaching the

muscular attachments found there; and then the external condyle of the humerus and the head of the radius. Then the edges of the sigmoid cavity of the ulna are cleared, and the insertion of the brachialis

FIG. 35.—Fracture of the epiphysis of the humerus by shell-splinter. Primary resection.

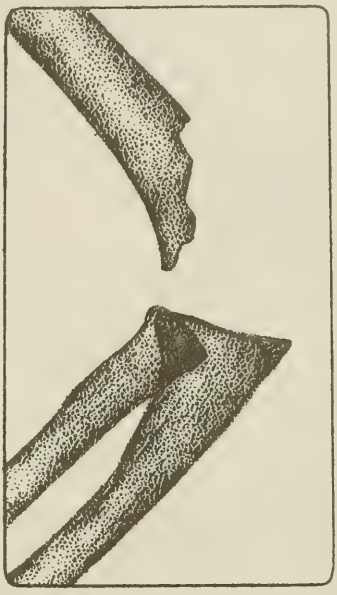


FIG. 36.—Radiograph taken four days after resection. Cure rapid with recovery of active flexion, extension, pronation, and supination. Complete cicatrisation in forty-five days.

anticus into the coronoid process, when the joint can be held wide open and the bones dislocated backwards.

When the rugine has freed all the bony surfaces by detaching the muscular insertions without cutting either them or the layer of periosteum to which they are inserted, the time has arrived for making the final bone sections. This is regulated by the line of fracture and the extent of the bony damage, but the object should be to make the section of the humerus through the thickness of the condyles, or just above

them where the shaft commences to widen. A section through the epiphysis just below the level of the epicondyle is the best if it can be managed.

In the bones of the forearm the section ought to be

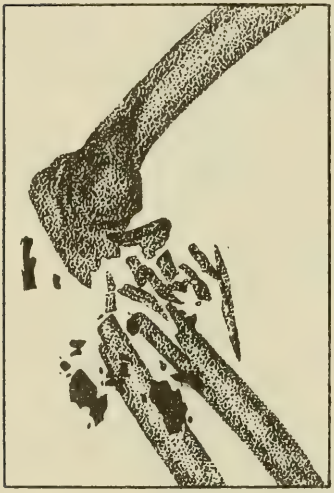


FIG. 37.—Fracture of the extremities of both bones of the forearm by shell-splinter, treated at the front by incision and immobilisation. At the end of fifteen days the patient reached me in a condition of full sepsis with high temperature and an enormous elbow-joint. The above radiograph was taken at that moment. Resection of the bones of the forearm was performed forty days after the injury.

FIG. 38.—The same after recovery, two months later. Extension is complete, but it is only effected by the triceps to 45°; flexion complete but ending in a sudden slipping of the ends of the bones of the forearm over the trochlea. A rather extensive resection of the epiphysis of the humerus would doubtless have had a better result by facilitating the adaptation of the epiphysis.

carried below the coronoid and through the neck of the radius.

Very often the articular end of the humerus is only fractured on one side, and the broken fragment carries with it a thin plate of the shaft: enough of the articular end remains on the sound side to enable the section to be through the epiphysis, which is sufficient if the

periosteum is preserved, for this latter will regenerate a new epiphysial mass.

Certain fractures may necessitate a section through the shaft : the procedure should then be confined to removal of the fragments without troubling about the shape of the bony extremities remaining. It is quite unnecessary to do anything for the fissures which divide the shaft longitudinally as if it were split. After the removal of the epiphysial fragments, everything is perfectly repaired (see figs. 7, 8, and 9). At most, the sharp ends may be smoothed off with cutting pliers.

When the fracture separates the epiphysis from the shaft, a large fragment is almost always found extending along the latter : of all the fragments this alone should be preserved ; the others are carefully stripped of their periosteum and removed. In this manner we preserve in an aseptic cavity the requisites for periosteal regeneration of bone, the completeness of which is surprising. The lower end of the injured shaft should always be freed and clipped off, for there the bone is of a reduced vitality and easily necroses.

But if it is necessary to be sparing in the removal of bone on the diaphysial side of the epiphysis, it must be realised that economy, as applied to resection in fractures localised to the epiphysis, is a mistake from the point of view of the future function of the injured joint. The results of a very limited removal are much less satisfactory than those of *free* resection : when the articular surfaces can come into close apposition immediately, all the benefit of resection as regards drainage is lost, and the functional result is endangered by the risks of ankylosis.

Moreover, if the movements of pronation and supination are to be obtained, complete removal of the head of the radius is essential. This is a view of the question that the partisans of hemi-resection do not take into consideration. Cases in which supination is

retained after that operation are very rare indeed; I have never seen any myself.

In a word, except in fractures where the loss of bone, shaft, and epiphysis in one of the articular extremities is much too considerable, it is better not to adopt hemi-resection either of the upper or lower half of the joint: they do not drain well, it often becomes necessary to complete the resection some days later, and besides, the functional result is always inferior to that obtained by complete resection. The reason of this is easy to discover: one of the articular ends being still covered with its cartilage cannot be moulded by movement, and the other is obliged to adapt itself to surfaces which are too complicated for its rudimentary shape; it has to do all the work of forming the new joint by itself, for which reason adaptation is more difficult and less perfect. In short, the ideal bone section is similar to that in a typical resection for tuberculous disease.

### IV. After-Treatment

1. **After Arthrotomy.**—A dressing of aseptic gauze is loosely packed between the bony surfaces round a small drainage tube inserted in the openings in the capsule. If the operation has been done early and if the clearing out has been complete, the joint ought not to suppurate, and through and through drainage is as unnecessary as is the use of antiseptics and lavage.

The chief desideratum in order to obtain a successful result is rigid immobilisation.

(*a*) This, however, should not be kept up for long, if all goes well: at the end of a week, if there be neither temperature, pain, nor oozing, movements should be commenced and attempts made to restore the free play of the joint.

Consequently it is needless to use a plaster case if the patient remains under observation. The limb

should be placed in a wire or aluminium splint, with the elbow at a right angle and the wrist slightly extended; the dressing should not be changed till the third day if possible, and then the drainage tube should be removed without touching the gauze.

Two days later the gauze should be removed and replaced by a smaller quantity. Two days later the dressing is repeated and movement begun, after which the splint is reapplied.

From this time forward regular daily movements of the joint are carried out, the limb being kept at rest during the night only.

Recovery occurs in one or two months.

(*b*) If, on the contrary, the exploratory arthrotomy has not been done early enough, or if foreign bodies, missiles, or splinters have been left behind, the wound suppurates freely and the treatment differs.

Two groups of cases present themselves for consideration.

The first is simply one of profuse suppuration without constitutional symptoms; after employing radiography to ascertain the cause (missiles, splinters), typical resection is, in my opinion, the indication, but this is only my personal opinion, and treatment may be limited to immobilisation in a plaster casing which will permit dressings to be applied without moving the joint or causing pain. There is no call to try to preserve the joint movements, for, in consequence of the suppuration, the joint is doomed to ankylosis. Treatment may be limited to rigid immobilisation, avoiding all movement until the infection has disappeared.

For the purpose of immobilisation a casing should be made with plaster bandages as follows: one bandage encircling the middle of the arm; another embracing the forearm, the wrist, and the slightly extended hand; two metal brackets to form a bridge, one on each side and a little to the front. This plaster casing is easy to make and to supervise, and fulfils the neces-

sary purposes. The forearm should be flexed at a right angle in the semi-pronated position, thumb upwards.

If suppuration of the joint is accompanied by constitutional symptoms, if there is a missile in the joint or splinters that requires to be removed, the best plan is to perform immediate resection. This is done in the manner indicated above: if the wound is left wide open, it will quickly become aseptic, and generally movements can be commenced at the end of a week or a fortnight after suppuration has ceased and the patient is free from fever. When the treatment can be well carried out, these "intra-febrile" resections give good results. I have done eight for war-wounds and have obtained seven good results, and one moderate one; the latter is getting better with the aid of massage, hot baths, and daily exercise.

2. **After Resection**: DRESSING.—After the joint has been cleared and the elbow bent at an acute angle, the wound is dressed without putting in any sutures. If desired, a drainage tube can be passed along the track of the missile; it goes without saying that this track is first opened up and cleaned by the curette, and that all débris is clipped away carefully. A little aseptic gauze can be used instead of a drainage-tube. The cavity of the joint is stuffed with gauze, without using lavage or any antiseptic. An absorbent dressing is placed on the wound and the elbow is immobilised in a wire splint, the hand being slightly raised with the thumb upwards.

As the wound sometimes oozes a good deal, it is best not to use the plaster apparatus, which would soon lose its shape and rigidity owing to the soaking by the discharges.

LATER TREATMENT.—If possible, the dressing is left untouched for seven or eight days. At the end of that time its removal causes less hæmorrhage than if it were done sooner. But often there is oozing of

blood-stained serum which may necessitate its earlier renewal. In that case the outer layers only are changed. An assistant holds the limb firmly, with one hand on the humerus and the other supporting the fore-arm, and upon him depends the amount of pain caused by the dressing. When the gauze is removed from the joint cavity, it is best to give the patient a whiff of ethyl-chloride ; a painless dressing is always better done. Later dressings will be done at longer intervals if one does not commence movement at once.

Sunlight Therapy or Hot Air.—Whenever the weather permits, it is beneficial to expose the wound to sunlight from the fourth or fifth day onwards. Its effects are marvellous. A quarter of an hour's sitting is sufficient to rid the wound of all the small sloughs which are seen upon it, especially at the first dressing, and to give it a healthy red appearance. After three or four sittings, the oozing completely stops and healing is proceeding rapidly. The muscles progress admirably.

If sunlight is not available, hot air can be directed over the wound for five minutes at a time : the effect is less rapid, but is none the less real.

Movement.—As soon as the patient has a normal temperature and is free from pain, the surgeon himself commences active movements, gently performing extension, flexion, pronation, and supination.

The aim should be never to produce pain which will put the patient on the defensive. After a few minutes of movement the limb is replaced in the splint. At the end of from a fortnight to three weeks, the splint is abandoned and the limb put up in a well-applied sling. After that the patient is left for some hours daily without the sling, so that when he tries to keep his forearm raised and flexed, he is bound to attempt some slight active movement. Soon he will begin to gain confidence in himself and to work

at it himself. Little result is obtained at first, but by advising him to try several times in the course of each day, progress is gradually made.

In the early days the recovery of active movements is much facilitated by compressing with the fingers the parts immediately above the elbow, thus giving more fixity to the ligaments of the joint, and allowing muscular action to be more easily effected. For this purpose I am accustomed to grasp the anterior surface of the arm with both hands, as is shown in fig. 39. The result is immediate: the patient begins to flex his forearm, gains confidence, and thenceforward works with a will.

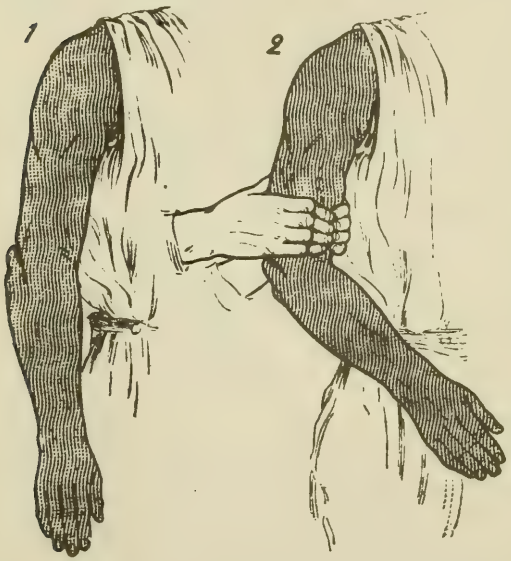



FIG. 39.—Method of commencing active flexion. The fingers are pressed over the new joint and give more power to the ligaments; active movement, which is not performed when the patient is left to himself, is effected to the extent shown in the second diagram when the elbow is squeezed.

In order to practise extension it is absolutely necessary to place the arm in the horizontal position, olecranon upwards, and to order the forearm to be raised. If that exercise is not carried out, the triceps does not recover its contractile power, and the movement of extension remains purely passive (see fig. 40).

It goes without saying that massage of the biceps and triceps should be commenced early. As soon

as flexion and active extension reach a point between 60° and 80°, all passive movement is abandoned and the patient does everything for himself. This daily task is one of patience to which he lends himself very readily if the elbow is left two or three hours at a time exposed to the sun. He becomes interested in his arm, follows its progress attentively, and learns how to work his joint. When this has happened, one can say that success is assured; but even then one should not lose sight of him: his efforts to go too fast must be curbed, and his desire to hurry must be restrained. He must learn that as soon as his move-

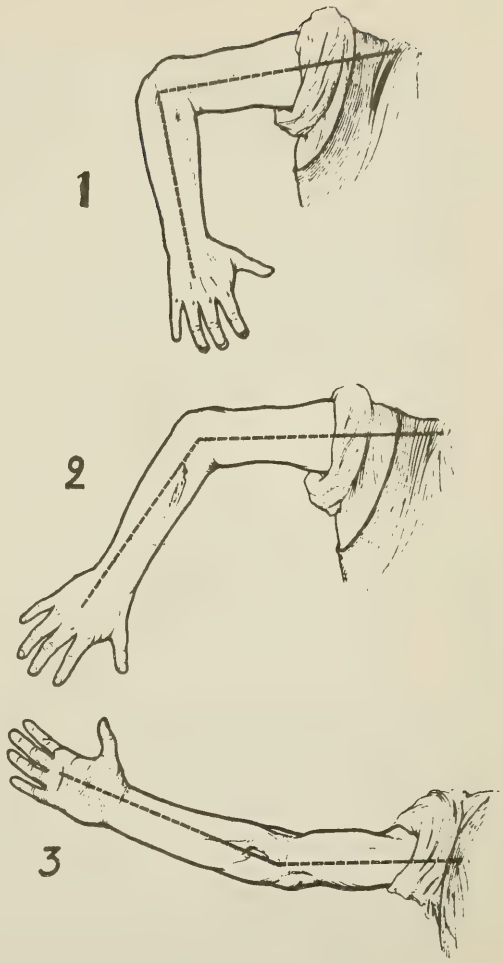



FIG. 40.—Method of making the patient perform active extension. This exercise will be combined with massage of the triceps. Comparison of diagram 3 with the two upper ones shows the difference between active extension and the passive extension occurring upon relaxation of the flexor muscles. The photographs were taken from a case which had been resected three months previously.

ments excite the least pain they must be stopped, and at times the joint must be immobilised again for some days so that it may be at rest. When a patient after resection complains of cramps in the muscle of the forearm, it is because there is periosteal irritation which tends to ossify the insertions of the muscles and demands rest. I never hesitate under these circumstances to put the limb in plaster for a week : much time is gained by acting thus on the first warning.

For all these reasons mobilisation cannot be effected by mechanical means, and mechano-therapy is of absolutely no value after resection. It is always a disadvantage.

In a word, the patient himself must be made to collaborate in his own cure by calling upon his good-will and his patience ; and ankylosis and a flail-elbow will be avoided by inculcating these precepts in him.

### V. Evacuation of Patients with Elbow Wounds

Patients wounded in the elbow ought not to be evacuated unless they have a bullet wound with punctiform openings ; all the others should be operated upon at the front as early as possible. They should only be evacuated early in circumstances of extreme pressure, and then ought to be left at the first surgical *relai*.

Those who have had arthrotomy done for slight injuries can be evacuated without danger after the third day if they are immobilised in a travelling plaster splint, the description of which will be given later on. The best time for evacuation for them is the eighth day, after the first attempts at movement have been made. Those who have been resected can be sent down without danger towards the fourth or fifth day. but the best time for them is about the fifteenth day, when the healing process has made good progress.

On their departure, each should have a detailed

statement indicating the stage of treatment reached, whether movements have been commenced or not, and giving suggestions upon the after-treatment.

**Travelling Splints.**—For the journey the limb will be immobilised in a large plaster casing covering the posterior and external surfaces of the limb, extending from the point of the shoulder to the lower end of the metacarpus. A slip of the splint is bent down into the palm between the thumb and the second metacarpal bone to form a strap, which fixes the splint and prevents it from slipping. The casing should only cover half the circumference of the limb. It should be made with twelve thicknesses of tarlatan. A cut is made just opposite the elbow to allow the splint to adapt itself to the flexed joint. The limb is semi-pronated and flexed at an acute angle, with the thumb upwards. The plaster splint is applied to the limb by a gauze bandage. As soon as the plaster is dry, this bandage is removed for fear it might become too tight, and is replaced by another, or what is better, by three pieces of strapping, one on the arm, one on

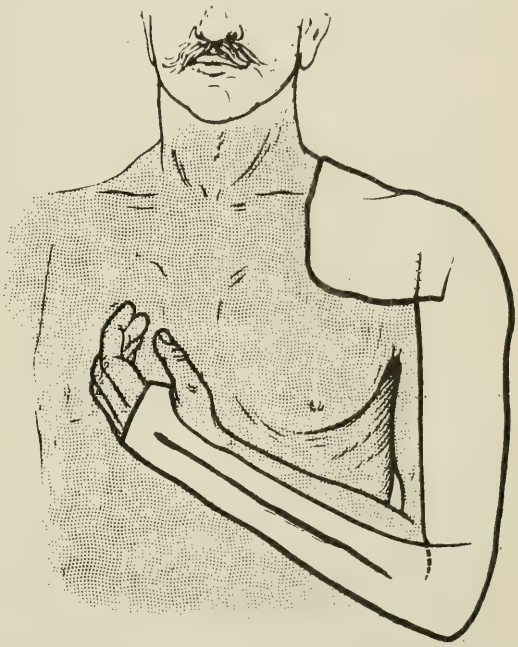


FIG. 41.—Travelling-splint for wound of shoulder. Between the dressings this casing can be used for permanent immobilisation.

the forearm, and one at the level of the hand. Lastly, a sling is applied to support the forearm and elbow. On the patient's arrival this apparatus is removed; the journey should not exceed forty-eight hours' duration.

### VI. Treatment of Patients seen late or after Evacuation

1. A PATIENT WHO HAS BEEN BROUGHT IN AFTER SOME DELAY, ARRIVES AT THE AMBULANCE AT THE END OF 24 OR 36 HOURS.—The elbow is swollen and painful, and sloughing muscle protrudes from the wound, pouring out blood-stained fluid. Immediate subperiosteal resection is the best treatment; it stops infection at once, avoids amputation, and ensures rapid recovery without sinuses or muscular atrophy. This result is obtained without the repeated operations which are so often necessary with every other method of treatment. I have had patients completely healed in forty days.

The after-treatment ought to be carried out on the lines laid down above.

2. A PATIENT IS EVACUATED AFTER CORRECT TREATMENT.—(*a*) *A case in which immediate arthrotomy has been done for parietal fracture or removal of a foreign body in contact with the bone* heals rapidly. At the end of a fortnight, immobilisation is abandoned and movements are commenced.

(*b*) *In the case of a patient arthrotomised for comminuted fracture, and doing well*, which is exceptional, ankylosis should be promoted by rigid immobilisation, and resection performed later. Premature attempts at movement in these cases may provoke symptoms of severe sepsis. While waiting for the final orthopædic operation the muscles should be gently massaged to keep them in good condition.

What position should be chosen for ankylosis? Classically the acute-angled position is the one of choice.

It permits the best use of the hand in private life, but it is not the position which gives the greatest strength to the hand. For manual workers a position at an obtuse angle (100°) should be sought for. According to the teachings of experience, that is the most useful position for the workman.

The objection is made that the workman is a private individual before being a workman, and that flexion at an acute angle is better in the case of the right arm, as it is with the right hand that one eats, dresses, etc. But as a matter of fact the first business of anyone wounded in the right arm is to become left-handed, when this objection falls to the ground.

There is no fixed rule and one had best follow the classical rule. But it is well to know of the argument so as not to worry about a joint which unites at a slightly obtuse angle; that position is not a bad one and ought to be left, unless the other arm is powerless or has been amputated, in which case the only good position is at an acute angle.

Which is the best time for an orthopædic resection if the patient's profession calls for one? It is not well to wait too long because of the condition of the muscles, or to interfere too soon because of periosteal irritation which must be left to settle down: from eight to ten months seems a suitable period.

It must not be forgotten that in certain callings requiring power in the arm, a painless firm ankylosis in good position should not be interfered with.

(c) *A limb that has been resected* ought not to be put up in a splint or an interrupted plaster casing and left to the tender mercy of any dresser to look after; it is as meritorious for a surgeon to supervise the formation of a new mobile joint as to do a brilliant resection operation.

In this kind of surgery, the operation itself is only one part of treatment: it is criminal to take no interest in the after-treatment because one has not

oneself performed the first part of it. This after-treatment ought to follow the rules given above.

3. A PATIENT INSUFFICIENTLY OPERATED UPON ARRIVES WITH PROFUSE SUPPURATION.—The affected part must be radiographed at once, and according to

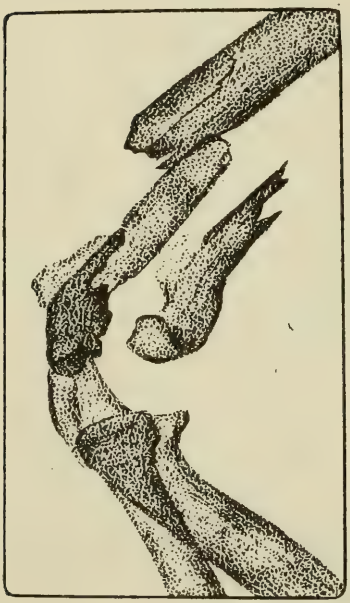


FIG. 42.—Fracture of shaft and lower epiphysis of the humerus treated at the front by limited esquillectomy, evacuated on the twenty-second day in a serious septic condition with adverse local symptoms. Amputation appeared necessary.

FIG. 43.—The same patient as fig. 42. Sub-periosteal resection with esquillectomy by the rugine had been performed on the twenty-fifth day. The radiograph shows the condition eight days later. The periosteum is already visible beyond the shaft.

the indications furnished by the presence of missiles or splinters, intervention must be practised.

Any missile must be removed.

Any suppuration which is of bony origin is the product of osteitis rather than arthritis. It must be

treated by operation. Multiple incisions doubtless sometimes succeed in obtaining the desired result, but these successive operations end by leaving ankylosis with sinuses, after severe pain, and a limb which is wasted, indurated, and furrowed with adhesions and scar tissue.

It is best to perform subperiosteal resection at once.

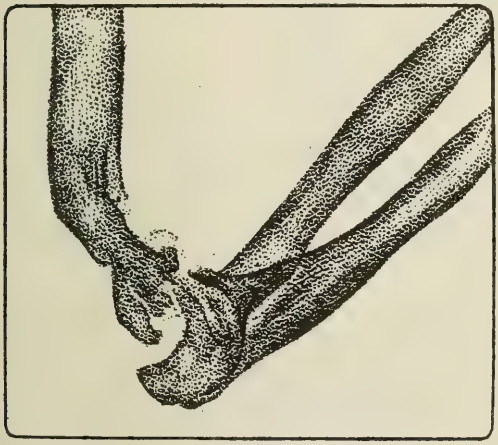


FIG. 44.—The same patient as figs. 42, 43, and 45. The same radiograph showing the maximal active flexion at the end of five months. The regular form of the regenerated extremities of the bones of the forearm and the adaptation of the newly-formed humeral callus are noticeable.

FIG. 45. — Full-face radiograph five months after resection, showing the degree of extension and the singular contour of the new epiphyses. The loss of substance on the inner side is probably due to the fact that the esquillectomy performed at the front was not done sub-periosteally.

If this be done exactly according to the rules given above, it immediately arrests infection and stops suppuration; after which one may obtain a remarkable anatomical and functional recovery (see figs. 44 and 45). Ollier himself had a tendency to prefer this late resection to the earlier

operation, which he dreaded on theoretical grounds, because he feared an insufficiency of periosteum which I have never met with after primary resection. I have done secondary resection eight times, with seven good results and one passable one which is improving. While preferring primary resection, the results of which are much more perfect

FIG. 46.—Casing, with spring for mobilising the elbow for use with timid patients or for those who have a flail-joint. In this latter case the apparatus will be removable to permit massage and exercise.

anatomically and physiologically, I consider secondary resection, early or late, an excellent operation. Technically in these cases it is well to be warned against a troublesome incident which may possibly occur in resection : while section of the humerus is being done, if one is not careful, the assistant in retracting the soft parts in front may reflect too much of the inflamed

periosteum and the denuded shaft of the bone projects prominently in the wound. This accident, which is easily avoided, is of no serious consequence; all that is needed is to repair it by fixing the periosteal sheath to the posterior muscles with a few catgut sutures.

As to the post-operative treatment, one of the troubles is combating the stiffening and inflammatory thickening of the muscles. A very hot bath, for half an hour daily, followed by gentle massage, with attention to movements, gives the best results in these cases.

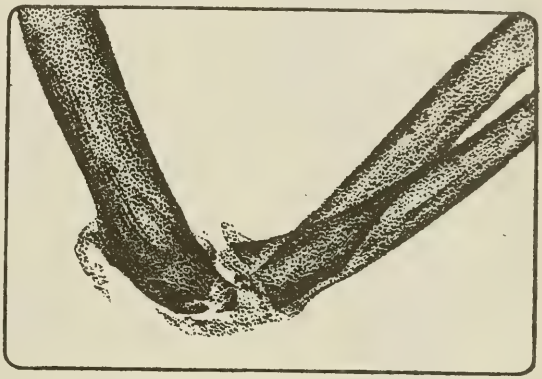


FIG. 47.—The three radiographs 47, 48, and 49 show three stages of the reconstruction of a joint after sub-periosteal resection of a massive fistulous ankylosis. In fig. 47 the outline of the olecranon and the indication of the formation of an epiphysis to the humerus are noticeable.

4. A PATIENT IS SEEN WITH A FLAIL-ELBOW.—This bad result is due either to a resection with very extensive loss of bone, or to bad technique in the operation itself or its after-treatment.

If the wound has not closed, a plaster casing with a spring must be made so as to get as complete an apposition of the bony extremities as possible, while permitting movement. This apparatus is easily made by two circular bandages, one for the arm and the other for the forearm, each about four inches in depth, strengthened by two springs of the shape shown in fig. 46. This apparatus should be left in position for twelve days, and then taken off daily for an hour

or two. To do this it is only necessary to cut the upper bandage down the back, and the lower one down the front, when the apparatus becomes detachable.

The patient takes a very hot local bath daily of about half an hour's duration to make his muscles supple. Then after careful drying he is massaged, and if possible has an hour's sun bath. At the end

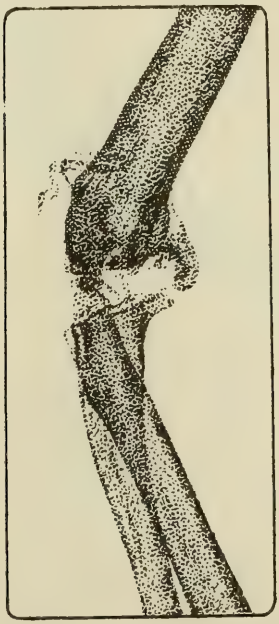


FIG. 48.—In this figure the olecranon is hidden behind the humerus and is invisible, but the formation of the humeral callus is very clearly seen.

FIG. 49.—Here are seen the olecranon, the coronoid process, and the trochlea. At this time (four months) active flexion reached 70 degrees, active extension was almost normal, and pronation and supination were complete.

of two or three months of this treatment the muscles will have become supple, and really support the loose new joint, so that better functional use becomes possible.

It is a great mistake, then, to abandon flail-elbows, or to fit them at once with artificial joints. The first

thing necessary is to restore the contractile power of the atrophied muscles. In this way unhoped-for success can be obtained. By this treatment I have restored useful active movements to a patient who had lost nearly five inches of the humerus, and whose arm hung useless at his side. If massage fails, before resorting to artificial limbs one should try to get ankylosis by refreshing the bony surfaces and suturing them, following this by prolonged immobilisation. It will still be possible to make a sheath of muscle and aponeurosis round the capsule by operation; reconstitution of the triceps ought thus to be quite possible.

A permanent jointed apparatus with a double armlet should be kept as a last resource in case of failure, or for patients who refuse further operation.

5. A Patient is seen with Ankylosis and Sinuses. —Immediate resection ought to be performed. It should be done widely, and the line of bone section should go high enough up the end of the humerus, and the whole of the sigmoid cavity and the olecranon should be sawn off. These are the extensive resections which give the best functional results, so long as the line of section runs across the humeral epiphysis. To ensure the recovery of supination, I am in the habit of dividing the radius with cutting pliers a little lower than the ulna; in that way the required mobility is much more easily obtained.

It is necessary to operate in the same way for vicious ankylosis and on those cases in which orthopædic resection is indicated (see p. 165). After resection, movement should be commenced in ten days and pursued according to the rules already given.

If the precepts of the sub-periosteal method are followed accurately, remarkable anatomical and functional results will be obtained (see figs. 47, 48, and 49). Up to the present time in wounds of this kind I have had twelve good results out of twelve operations undertaken for orthopædic reasons.

## CHAPTER IV

## WOUNDS AND FRACTURES OF THE WRIST

### I. Anatomical Types and Clinical Course

From the point of view of classification there are three etiological, three anatomical, and two clinical varieties of gunshot wounds about the wrist.

Etiologically these are :—

*The bullet wound* with small skin orifices, very limited fracture and tunnelling of the bone without comminution, which recovers quickly and well with partial ankylosis of the carpus.

*The small blind wound caused by a shell-splinter*, a tiny hole with contused edges, in appearance nothing, but leading rapidly to an acute arthritis of the wrist.

*More or less considerable destruction of the carpus*, the result of a bullet fired at close range or of a shell-splinter. This type is very common, especially as a large wound on the dorsum of the wrist.

Anatomically the injuries may be purely carpal, especially in the two first groups mentioned above. They affect the radius or ulna fairly seldom and very often are carpo-metacarpal.

Clinically, the course is usually mild at first : these wounds scarcely ever give rise to gas gangrene or septicæmia, because, being wounds of exposed parts of the body, they hardly ever contain fragments of clothing, and because, being wounds involving

skin and bone only without extensive damage to muscles, they do not provide the conditions essential to the development of severe infection.

The danger is suppurative arthritis, the course of which is sometimes very insidious, but which demands rapid action for its treatment.

Many widely gaping wounds, freely exposed to the air, heal well, but considerable loss of power persists in consequence of the destruction of tendons, displacements of the metacarpal bones and fingers, which often necessitate subsequent corrective amputations.

### II. Primary Therapeutic Indications

Because these injuries have no immediately severe symptoms, it does not follow that they should be neglected : at the outset one has the power of directing their course by rendering them aseptic, and is able to save the patient much suffering, and to reduce to a minimum the permanent damage that must ensue.

Operation must therefore be practised as early as possible.

Four methods of treatment are open to discussion.

1. **Immobilisation pure and simple.**—This is suitable for wounds caused by long-range bullets. After painting with iodine and applying an aseptic dressing, the hand is placed in a position of slight dorsi-flexion in a palmar plaster splint, extending from the heads of the metacarpal bones to a little above the elbow. Passing the thumb through a hole in the plaster splint is an excellent means of fixing the apparatus and of applying it satisfactorily to the forearm. This splint is kept on for three weeks, when gentle movement is commenced. Complete recovery takes place in one and a half or two months. Sometimes vaso-motor or nerve troubles persist without apparent reason ; they may be considered as a sympathetic neuritis, and treated, as I have elsewhere indicated, by excision

of the cellular sheath of the brachial artery, which is covered with nerve-plexuses.

2. **Esquillectomy.**—In the carpus, where it is always really a partial resection, this operation is suited at the outset to all fractures limited to the carpal bones, whether there be a blind wound or a penetrating one with the wound of exit more or less ragged. It is economical, that is to say it will only affect the bone (semi-lunar or os magnum) or bones directly struck by the missile. If done in the prophylactic stage, there is no need to be afraid of the many recesses of the synovial membrane. When disinfection is done early, the carpus can be considered as composed of one bone only, and if the disinfection has been carefully performed, esquillectomy is practically always sufficient to give a good orthopædic result.

It is the method of choice for all blind wounds of the wrist and the small contused wounds made by grenade splinters, in which serious arthritis of the wrist sets in very rapidly if one does not intervene. In these cases early incision followed by removal of the fractured bone is a matter of great urgency; unless partial resection is performed, total resection will have to be done in a short time, and the functional result of that is quite another matter. When the fracture involves in addition the lower articular ends of the bones of the forearm, a very limited esquillectomy will be done upon them, bearing in mind the usual mildness of septic infection in this region. As much as possible should be preserved, especially the styloid processes, which are always required to prevent future lateral displacement.

When the fracture involves both carpus and metacarpus, as little should be done to the latter bones as possible, especially if the tendons are intact or only slightly damaged. Fractures of the metacarpus generally recover well. The functional result is often better than one expects. If, however, there is much

loss of tendon and therefore no hope of satisfactory restoration of function, less restraint is necessary since the corresponding finger is hopelessly damaged.

But in principle it is best to be extremely conservative in the case of both hand and fingers, since no one can foresee the extent of the eventual recovery of function of a deformed hand.

Fig. 50.—A splinter had entered the ulnar side of the forearm, blowing away a portion of the ulna, and had passed through the carpo-metacarpal area, lacerating the tendons of the three middle fingers, and breaking up the corresponding metacarpal bones. Severe sepsis. Esquillectomy of the ulna, disarticulation of three fingers and their metacarpals, and removal of the os magnum have obviated amputation, which appeared necessary.

3. Typical Resection.—Naturally this operation is only exceptionally called for. It should be reserved for serious bony injuries, for destruction of the carpus when all the cancellous tissue is crushed: in these cases it is performed without worrying about accompanying lesions of the tendons and muscles, if the vessels and the nerves are intact. The principle is to preserve the hand somehow, and besides, when intervention is done very early and a practically aseptic course can therefore be hoped for, the divided tendons can be sutured.

4. Total Amputation of the Hand.—The only indication for disarticulation at the radio-carpal joint,

or amputation through the forearm, is complete crushing of the hand, when the surgeon merely finishes what the missile has begun. Whenever it is possible to preserve even a broken metacarpal bone with its corresponding finger, an atypical ablation of the injured part is preferable to total amputation. Every effort should be made when the thumb is in question. Loss of the hand should be avoided at all costs.

For this purpose limited amputations of one or

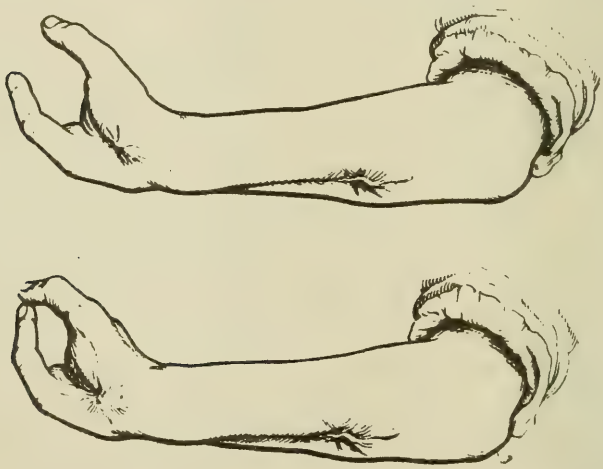


FIG. 51.—Disarticulation of the three middle metacarpals with partial resection of the carpus and free esquillectomy of the ulna. The lobster-claw action from a photograph taken six months after the injury: the patient can make a cigarette, placing the paper on a table.

more fingers, combined with partial resection of the carpal bones, should be freely used. When, for example, an injury to the wrist is accompanied by total destruction of three metacarpals and their tendons, they should be removed with their corresponding carpal bones, leaving only the internal and external supports of the carpus. The lobster's claw thus made will be all the more mobile. Doubtless in these cases it might be possible at times to cause the disappear-

ance of septic phenomena by means of a limited esquillectomy, but recovery is difficult and leaves fingers ankylosed, deformed and immobile, and calling for removal later on. Manifestly the sacrifice of the metacarpal bones should not be lightly made : it is only allowable if there is no hope that their corresponding fingers will ultimately recover their mobility. It will be said, perhaps, that there is always time to intervene later if there is occasion to do so, and that it may then be possible afterwards to limit the operation to removal of the fingers. But as a matter of fact the free drainage provided by ablation of the carpus and metacarpus favours recovery without the formation of septic cavities and without cellulitis of the tendon sheaths, but with perfect use of the other fingers, which is of the utmost importance. On the other hand, whenever one removes two fingers, it is best to remove their metacarpal bones as well, to allow of a better approximation of the remaining digits. Similarly, when one finger is removed, it is best to resect the head of the metacarpal to diminish the interdigital space.

These combined operations are perfectly legitimate and almost always enable one to avoid total amputation of the hand.

Finally, the operation which will be most frequently performed, for the purpose of early disinfection, is that of partial resection, either limited to one or extended to several bones of the carpus, with the addition, if need be, of one or two metacarpals.

### III. Operative Technique

As a rule, every operation on the wrist for war-wounds is decidedly atypical. Whatever be the precise technique chosen, two important rules ought to be borne in mind.

The incisions should run as parallel as possible to, and to one side of, the extensor tendons.

The denudation of the bones ought to be done with the rugine, with which the periosteum, the ligaments, and the muscular insertions will be separated. It must be remembered that the life of tendons is precarious since they slough easily: if great care is not used in exposing them, cicatricial contraction and adhesions will jeopardise the result.

(*a*) Access to the Joint.—When a blind wound, or one of limited extent, is concerned, the bone should be reached and exposed by excising the wound of entry, which is practically always dorsal. If the sacrifice of one or more digits appears necessary, it is best to commence the operation by a carpo-metacarpal disarticulation, which freely exposes the depths of the wound.

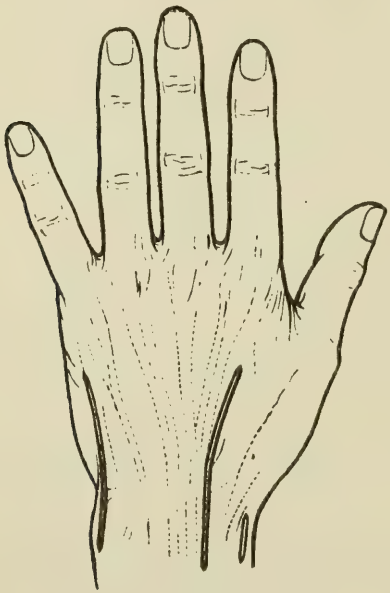


Fig. 52.—Para-tendinous incisions for resection of the wrist.

If the injuries appear to necessitate merely an extensive resection of the wrist, Ollier's two para-tendinous incisions—the one metacarpo-radio-dorsal, the other ulno-lateral—should be employed to expose the carpus whenever the wounds permit. The former follows the radial border of the extensor indicis: it extends from the middle of the line joining the two styloid processes as far as the middle third of the second metacarpal bone.

After the tendon has been defined, the incision is carried down to the periosteum and the dorsal ligaments, avoiding the tendon of the extensor carpi

radialis brevior, the insertion of which is hidden by the extensor indicis tendon. The periosteum is incised over the inner edge of the head of the third metacarpal, where the rugine will commence to raise the capsulo-periosteal sheath.

The ulnar incision commences a little above the styloid process of the ulna and runs down to a point 1 in. above the lower end of the fifth metacarpal, nearer its palmar than its dorsal aspect, so as to leave the tendon of the extensor carpi ulnaris in the dorsal margin of the wound. This incision, which crosses a cutaneous branch of the ulnar nerve, which should not be cut, exposes the cuneiform and the unciform bones. It is needless to go over the remaining stages of the operation : they comprise division of the posterior annular ligament to allow retraction of the tendons, denudation of the bone, and extraction of fragments by means of the rugine : they are all easy enough.

Incisions over the outer side of the radius should be avoided as much as possible, because of the presence of the radial artery.

### IV. Post-Operative Treatment

1. A CASE OF TOTAL RESECTION OF THE CARPUS will be immobilised in a plaster casing after an aseptic dressing has been applied.

This will be done in the following manner :

Six double thicknesses of tarlatan are cut to make a splint extending from the lower third of the arm to the level of the transverse palmar crease, leaving the fingers free. A prolongation will slightly separate the thumb from the index finger, which is the best method of obviating loss of opposed action later. The splint only covers half the circumference of the limb, which is semi-pronated, with the hand in a position of dorsi-flexion. The hand must be well supported.

At each dressing the splint is removed and the hand carefully kept dorsi-flexed by an assistant. If the plaster has softened, it must be renewed : it is of importance that immobility should be perfect. The

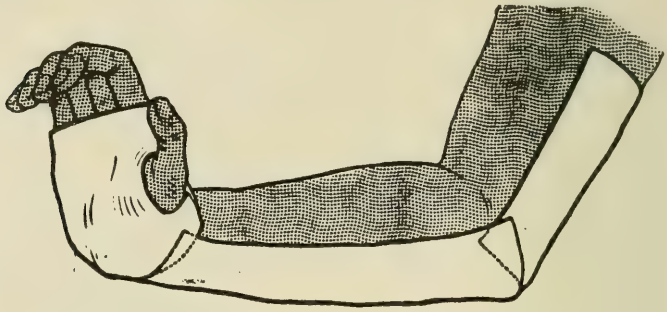


FIG. 53.—Casing for immobilisation of the wrist.

plaster is kept on for several months. The hand has a constant tendency to fall, both on account of its own weight and of the predominance of the flexor over the extensor muscles. At an early date passive and active movements of the fingers will be commenced ; these soon get stiff if they are not moved, and are

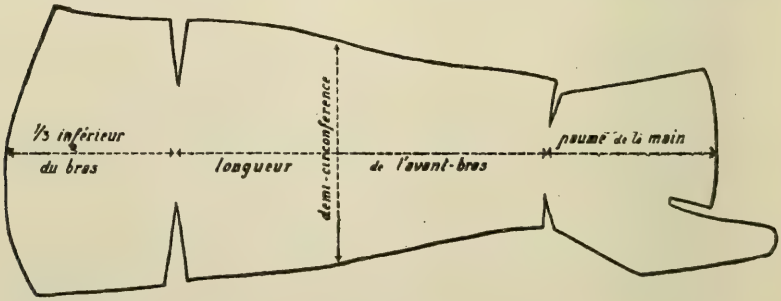



FIG. 54.

then very difficult to restore to their normal mobility. Interrupted plaster splints ought not to be used at the wrist, because they do not leave the fingers sufficient liberty of movement. In fine, one ought never to lose sight of the double object to be attained : fibrous

ankylosis of the wrist in good position, and mobility of the fingers.

2. In Partial Resection it will be quite otherwise. One can and ought to restore free movement to the wrist: the hand has no tendency to fall or to deviate from its proper position. At an early period exercises ought to be commenced, so as to produce a supple carpal joint. If all local and constitutional symptoms of sepsis have disappeared, they will be undertaken as early as the eighth day, and should be progressive and gentle, first passive, and later active. There is no need for hurry: it is a question of patience, not speed.

In the intervals between the movements the limb is replaced in the plaster splint, which will not be finally discarded until after a fortnight or three weeks.

3. In Partial Carpo-metacarpal Amputation it will be well to employ hypertonic saline solution as a dressing for a week. When the wound is not perfectly aseptic, a little arthritis develops round the carpus: this is shown by an œdematous swelling of the hand, which a dry dressing does not easily subdue. The osmotic currents produced by the concentrated saline solution hinder absorption in the many synovial sacs exposed and favour the cure.

This moist saline dressing does not permit the limb to be retained in the plaster casing. During this period, therefore, the hand is supported in a position of slight dorsal flexion upon a wide wooden splint, the hand part being firmly padded with sterilised cotton wool. The splint ought to extend up as far as the upper third of the forearm to make the patient comfortable.

After eight to ten days of these moist saline dressings, which are renewed daily or every second day, according to the temperature chart, the ordinary dry aseptic dressing is reverted to. At an early date,

mobilisation of the fingers and phalanges will be considered.

### V. Evacuation of Patients with Wrist Wounds

No one wounded in the wrist should be evacuated without primary operation except he be a case of bullet wound with punctiform openings. All should be operated upon with the least possible delay, as has been indicated above.

At the end of forty-eight hours, if the operation has been sufficiently radical and all is going well, a patient who has undergone partial resection can be sent out without risk; if he has had total resection done, eight days ought to be allowed; and the same period, or a little less, if partial amputation has been performed and the result appears favourable.

The limb should be immobilised in a plaster apparatus, made as described above, viz. a palmar splint extending from the flexure of the fingers to above the elbow, the hand being slightly dorsi-flexed. The plaster should be removed and reapplied on arrival. The journey should not exceed twenty-four hours.

### VI. Treatment of Patients seen late or after Evacuation

1. When a Patient, who has been operated upon early, arrives in good condition.—He has undergone a primary resection, partial or total, of the carpus, and he ought to recover rapidly with movement of the joint (in case of local removal of bone), or with ankylosis, if the after-treatment is suitably supervised, as has been set out above.

2. A Patient, who has not been operated upon, or has been insufficiently incised, arrives with Arthritis of the Wrist.—This arthritis practically always involves the whole joint. Normally, the wrist-joint possesses many distinct and independent synovial

membranes, but they have many contiguous diverticula, they are in immediate contact, and there are often minute channels of communication between them. As soon as one of these is opened and becomes infected, the different articulations are rapidly attacked, as if there were but one synovial membrane and one articulation. On the other hand, if a missile traversing one of the bones has been stopped, as it often is, at the palmar surface in contact with the synovial sheaths, there is almost always a deep abscess there and this can only be opened and drained by extensive resection. This is not the time for limited arthrotomies and economical resections. Partial resection is as valuable as a primary operation as it is detestable as a secondary measure. Complete removal of the carpus should be effected at once; it is impossible to remove a single bone without opening the neighbouring serous membranes, and, if they are invaded, intervention has only served to spread the mischief.

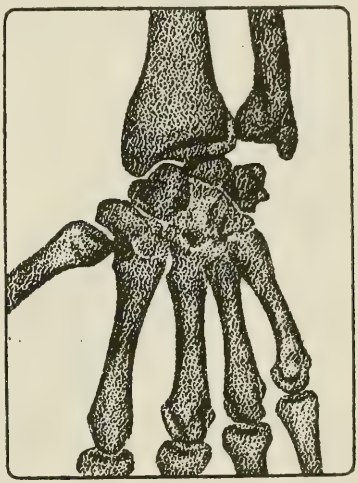


FIG. 55.—Secondary arthritis of the wrist after a blind wound caused by shell-splinter. The patient, retained in a hospital at the front for a wound of the skull, was evacuated on the twelfth day with a small dorsal wound of the wrist apparently doing well. The radiograph taken on the fifteenth day showed a small projectile and a blurred appearance of all the metacarpal bones; the wrist was rather swollen and painful, the patient slightly febrile.

On the other hand, if one delays, the synovial sheaths of the flexors are attacked; purulent foci are formed in the forearm, the constitutional symptoms become worse, and the function of the hand is definitely endangered. Certain parts of the carpal bones, viz. the

unciform process and the tubercle of the scaphoid which constitute the lateral boundaries of the palmar carpal groove, have their periosteum intimately blended with the synovial membranes of the flexor sheaths; their infection must be prevented at any cost, and to ensure this, total resection of the carpus should be done without delay; besides, it gives excellent results and avoids secondary amputations.

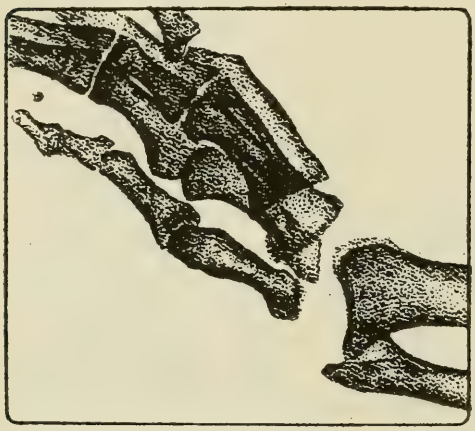


FIG. 56.—The same case as fig. 55. Exploration showed that the splinter had passed through the os magnum and was embedded in the palmar ligaments. The bones of the carpus had all lost their cartilaginous covering, except the upper part of the scaphoid and the semilunar. There was a large palmar abscess spreading along the sheaths towards the forearm. The rather unusual aspect of the plate is due to the position of dorsal flexion in which the hand was immobilised. Radiograph taken three days after operation, which gave a good result.

But the situation may be more complicated: when a splintered carpo-metacarpal fracture exists and has not been sufficiently cleared out and there are signs of severe general infection, any fresh interference provokes an acute attack of general arthritis of an extremely violent type, accompanied by formidable general and local symptoms, which seems to demand amputation. There is, in short, a dangerous period in secondary intervention for injuries of the wrist. Does this mean that at this stage it is a question of doing nothing or of amputating? Not at all. The post-operative complications are owing to the fact that surgical interference roughly opens up the joints in

the vicinity of the one primarily affected and infects them.

In order to prevent operation from being followed by bad symptoms, and in order to avoid this acute arthritis, it is necessary immediately to expose the carpus in the neighbourhood of the injury and either remove it or the broken metacarpal bones and the damaged tendons. By laying the cavity widely open and combining partial resection of the carpus with amputation of the metacarpals and fingers which have been injured, the sepsis is limited and a hand, though a poor one, is saved.

To sum up, these cases are not to be treated by esquillectomy or by local operations, but by combined amputation and resection, followed by dressing with a hypertonic salt solution and by satisfactory immobilisation.

3. When a Patient is seen late with persistent Suppuration.—If there is an obstinate sinus, limited resection by means of the rugine is indicated.

If some of the fingers are deformed or drawn out of position and useless, appropriate disarticulation can be done.

Troublesome tendinous adhesions are remediable by the interposition of fatty grafts between the cicatrices and the tendons. I have obtained excellent results by these means.

## CHAPTER V

## WOUNDS AND FRACTURES OF THE HIP

### I. Anatomical Types and Clinical Course

WOUNDS of the hip-joint appear rare when we consider the frequency of joint wounds in general. This is not due to the lucky escape of this deeply seated joint but rather to the extreme gravity of the wounds, a great number of which are accompanied by fracture of the pelvis, injury of the bladder, and perforation of the intestine, and rapid death is the usual result. Besides, bullet wounds with explosive effects produce in the massive muscular covering of the hip such formidable damage, and such destruction of vessels and nerves, that immediate death from shock and loss of blood is very common. In this way many wounds of the hip-joint escape observation, and the number is reduced to those one is called upon to treat.

In practice the following types must be distinguished :

(*a*) *A Bullet Wound with punctiform skin-openings.*— The bullet perforates the neck or the head of the bone under most variable circumstanes, producing perhaps a limited injury (furrow, perforation, erosion), or perhaps bony damage which, though considerable, may yet run an aseptic course. Usually voluminous callus is formed and there is ankylosis of the hip.

(*b*) *Cancellous crushing, with a retained missile.*— This is the starting-point of progressive osteitis : according to its position, in the neck or the head of

the bone, articular osteitis is more or less early in appearing. But as a general rule, an acute suppurative arthritis is developed, which may lead to a rapidly fatal result if immediate intervention is not undertaken, or to a less acute form of the disease which leads to ankylosis after pretty severe suppuration.

(*c*) *Separation of the head of the femur.*—This is a

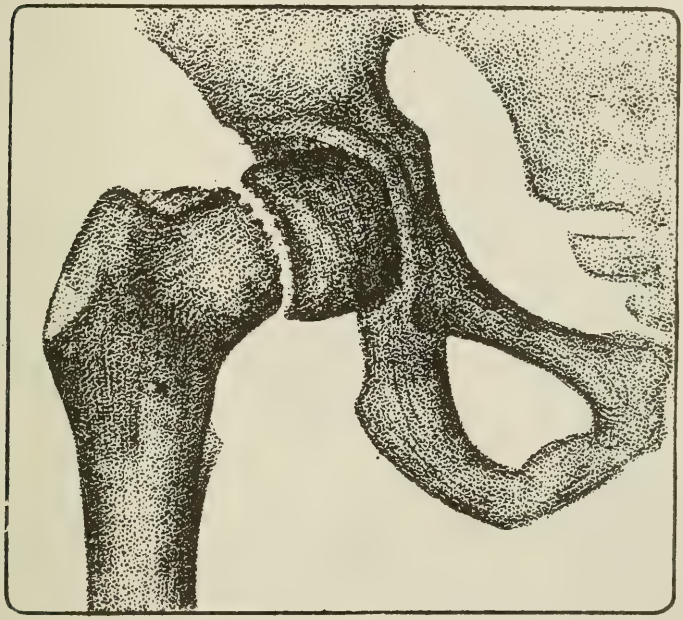


Fig. 57.—Separation of the head of the femur by a shell-splinter with a postero-anterior wound. Primary resection by anterior incision. Recovery.

frequent injury arising from shell-splinters coming from a height. At first the trouble may appear slight, but towards the third or fourth day an acute arthritis develops, with septicæmia and suppuration of the neighbouring muscles of a sloughing type. The head of the bone forms a deep-seated sequestrum, and if it is not removed without delay death pretty certainly supervenes.

(*d*) *Transverse fracture through the trochanters.*—The projectile entering at the great trochanter finds its way towards the lesser one, above or below it, without, as a rule, interrupting the continuity of the shaft. But the violence of the injury has an extremely severe effect within the joint, which it is always important to recognise and look out for; a fracture of the neck is caused by contre-coup. In consequence of the infection produced by the passage of the missile, there is rapid development of a gangrenous articular osteitis of a very grave type which is almost always fatal.

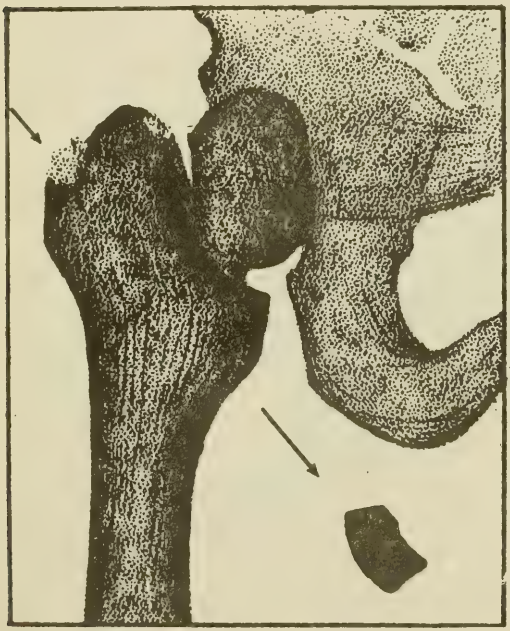


FIG. 58.—Fracture of the neck by contre-coup, the wound passing through the trochanter. The separation of the head of the humerus was not recognised in the absence of radiography. Later resection of the head did not prevent the death of the patient by sepsis. Early resection would have been followed by recovery.

(*e*) *Smashing of the hip.*—This is seen sometimes in large wounds of the outer side of the thigh and the buttocks which do not involve the femoral vessels and sciatic nerve. The wounded, who are always under the influence of extreme shock, may survive, but quite exceptionally. The enormous damaged area of which the joint is the centre is ready to become infected, and, unless rapid intervention is undertaken,

an acute gangrenous septicæmia rapidly carries off the patient.

Each of these fractures, whatever the type, may be single, but more frequently fissures of the acetabulum or of the iliac bone accompany them. At other times they are associated with visceral lesions, vesical fistulæ, or ruptures of the colon. These are grave complications which make it all the more urgent to practise an intervention capable of enabling the osteo-articular injury to run an aseptic course. In all these cases the prognosis should be very guarded.

### II. Primary Therapeutic Indications

It is well to put on one side, as usual, those cases of bullet wounds with very narrow cutaneous openings, the treatment of which is identical with that of simple fractures; that is to say, immediate immobilisation in a plaster casing extending from the back of the pelvis to below the knee, or in a plaster spica enclosing the whole lower limb, which is fixed in a position of extension and abduction. The extension should be kept up while the plaster is being applied, unless it is going to be applied secondarily. The patient recovers with ankylosis and often with marked shortening. It is unusual for the seat of fracture to be infected primarily, but an obstinate sinus is not an unusual after-development: I have seen several examples of it. Barring these cases, which are becoming less and less frequent in trench-warfare, all other wounds of the hip and all those caused by splinters of shell or grenades ought to be operated upon at once, because from the first they are all in imminent danger of severe infection. Owing to the depth of the joint and the difficulty of reaching it, one is doubtless tempted to immobilise the limb and wait for symptoms of the onset of infection before doing anything further. But this is a deplorable course to take: at the hip, the necessity of operative

measures which are prophylactic against infection is as pressing as anywhere else, if not more so. If the patient is suffering from shock, he must be treated by means of the usual stimulants (oil and camphor, artificial serum)—morphine is very useful in severe cases of shock—and then early operation must be undertaken without waiting for the clinical signs of established septic poisoning.

Three operations have their indications and must be considered.

1. **Limited Esquillectomy and Drainage.**—Theoretically this operation is suited to partial lesions, to some degree extra-articular, as for instance certain marginal fractures of the great trochanter. But the frequency of fracture by contre-coup of the head or the neck limits the employment of it in practice. One should never admit *a priori* that a fracture of the trochanter is the only one, until radioscopy has proved that it is so, and unless it is a case of incomplete cancellous crushing caused by a missile which remains *in situ*.

Simple esquillectomy is scarcely ever indicated for injuries which are properly speaking articular. Indeed, at the hip it is very rare to see partial and limited injuries; in consequence of the anatomical conformation of the upper extremity of the femur, one sees hardly any but complete fractures such as those of the neck and head, and, for my own part, I have never met with any others. Hence it can be seen that, the joint being a very close-fitting one, arthrotomy is an illusory operation, and it is only by wilfully deceiving one's self, that one can hope for anything from it.

The objection has been raised that patients have recovered after drainage through the buttock or thigh; but to begin with, *were they cases of articular lesions?* The mistake is so easy. Let us admit that some recover, as anyone can see for himself. But these are only fortunate exceptions: under the big muscles covering the hip-joint, simple drainage cannot suffice

to cure a deep-seated osteitis, which elsewhere requires resection. It is certain that the patients who have died or have suffered from obstinate sinuses are much more numerous.

It is said, too, that it is difficult to do anything else, and that simple drainage round the joint will always remain the method in general use. But I cannot think that this is founded upon precise anatomical and clinical data : this treatment by drainage is not adopted because of the good results it gives, but by reason of timidity in operating, and of a general want of precision in diagnosis. One fact dominates the situation : the mortality from sepsis is considerable among those who have escaped death from shock or hæmorrhage, and operations for drainage without free removal of bone do little to diminish this secondary mortality. Logically it cannot be otherwise. There is no reason why a joint so deeply situated should not follow the usual course of wounds of joints, and it should be admitted as a principle that, except in very rare cases, justified by radiography, a blind esquillectomy cannot constitute a sufficient method of treatment for wounds of the hip-joint.

2. **Resection.**—It is quite different with resection, which, while it removes the head of the femur, gets rid of the principal lesion, and freely exposes the seat of injury : under these circumstances no infection ensues, and the wound progresses without complications, like all war-wounds which are treated logically and in time. Resection has the further advantage of permitting direct treatment of the rim of the acetabulum, or the bottom of its cavity.

The only objection that can be urged against it is the poorness of its orthopædic results. When, in order to remove the head which has been separated from the neck, or to saw through the neck in front of the trochanters, a free denudation of these latter is

carried out, the insertions of the muscles into the trochanter are more or less disorganised, the external attachments of the capsule are destroyed, and the upper extremity of the femur is gradually dislocated upwards and backwards on to the ilium. If to this is added the loss of power resulting from the damage done to the muscles and nerves of the buttock it is easily understood that the result, so far as the function of the joint is concerned, leaves much to be desired.

It is true that the wounded survive, and that is a consideration. But there is more than this to be said: the functional result after resection can be much improved by making an anterior incision leading straight on to the neck and head of the bone, which allows resection of both with a minimum of damage. Under these circumstances, the orthopædic result is excellent, and resection becomes an operation at once conservative, beneficent, and useful. Resection should be employed at once then for all fractures of the head and neck caused by splinters of shell and grenade, or by a bullet fired at short range.

3. **Disarticulation.**—When there is considerable damage of the explosive type, when the fracture involves both shaft and epiphysis, when the upper third of the femur is reduced to fragments, early disarticulation, immediately the shock has passed off, or has sufficiently abated, is indicated as the only chance of saving life.

To sum up, primary resection by an anterior incision applies to almost all the fractures of the head and neck which do not cause immediate death, and to all those in which preservation of the limb ought to be attempted. The others are amenable only to disarticulation.

### III. Operative Technique

1. Resection.—Resection should be performed in as typical a manner as possible; the orifices of entry

and exit, without exception, ought only to be used as means of drainage, not as means of access. Classically, the most direct incision to the hip is the postero-external one; most often it traverses the whole length of the gluteus maximus, crosses the medius and minimus, and finally, after opening the capsule, severs the tendinous attachments of the glutei muscles and those between the trochanter and the pelvis. This method has the great advantage of draining at the lowest point, but the orthopædic result is only moderate. There is no ankylosis, and the femur slides over the iliac bone in a position of marked adduction.

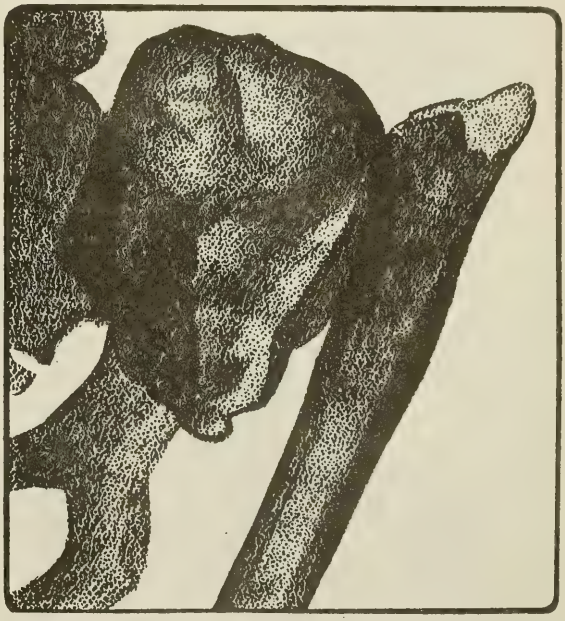


FIG. 59.—Luxation of the femur on the ilium after resection by a posterior incision. Compare this with the result shown in fig. 60. (Radiograph contributed by Berard.)

The anterior incision, which exposes the joint without sacrificing any muscles or nerves, gives a very much better orthopædic result. By preserving intact the insertion of the gluteus medius and minimus, the muscles passing from the pelvis to the trochanter and the most important part of the capsule, it favours ankylosis and consequently ensures a satisfactory result. It is, moreover, easier

to perform and does not inflict any severe operative damage; on this ground it is specially indicated as the primary operation of choice. To realise its advantages the technique advised by Berard, and used by him with excellent functional results, should be employed.

In this method the anterior incision follows the long axis of the head and neck, starting from the anterior inferior iliac spine to end a little below

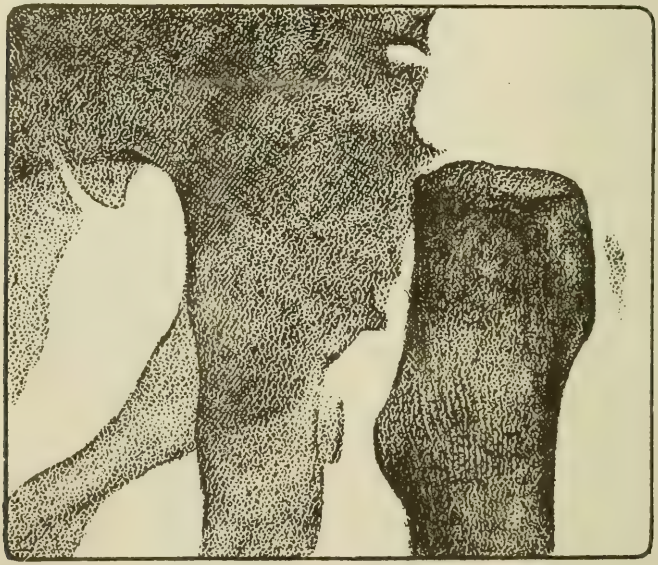


FIG. 60.—Resection of the hip by anterior incision. (Radiograph of a case operated upon by Berard.)

the top of the trochanter. It thus opens up the space between the tensor vaginæ femoris and the gluteus minimus on the outside, and the external border of the sartorius and the psoas on the inside. The muscles are well retracted, the thigh is semi-flexed and slightly abducted, and the capsule incised along its whole length. Each edge of the incision in the latter is held by forceps and divided transversely at the level of the brim of the acetabulum, and this releases the

circumference of the head. It is then easy to remove the fractured parts. Then posterior drainage is established by the aid of a pair of forceps introduced into the wound and made to protrude in the buttock, where they seize a drainage tube. The edges of the wound of entry are then trimmed with as much care as if resection had not been done; the sloughing muscular tissue is excised, the missile is removed, and, if necessary, the trochanter is carefully curetted. Then the operation wound is closed. The idea dominating all this detail is to put the wounds caused by the operation and the injury into such a condition that they may run an aseptic course.

2. Disarticulation.—The patients whose wounds call for this form of treatment always arrive in a state of extreme shock. The indication is that intervention should only be undertaken after an interval for rest and recovery. The operation should be the simplest and least violent; that is to say, one should commence by amputating the thigh, straight through its upper third after ligaturing the femoral vessels at the level of the section; then a free incision is made from a little above the trochanter down to the circular incision. This gives two large muscular flaps out of which the injured femur can be easily and rapidly removed.

This cavity is left wide open without sutures, and dressings are applied flat to its surface. Immediate intra-venous injection of artificial serum in large doses (1 to 1½ litres) will complete an operation, which, if performed without delay, will save the lives of some who would die if rapid action were not taken.

### IV. Post-Operative Treatment

We shall only deal with the treatment after resection.

(a) *Dressing and Immobilisation.*—The wound is packed with aseptic gauze and a large spica bandage

applied, with wool over the posterior part. In order to do this dressing without disturbing the resected joint and while keeping the limb in good position, three supports should be placed beneath the patient, one under the head, another in the middle of the back, and the third under the buttocks. Another apparatus, resembling what Ollier describes as his "pelvi-cervico support," may be preferred. For this three simple padded rests are used; the cervical support is hollowed out and is a little higher than the others. They are all three arranged on a board, the two upper ones being moveable and the lower one

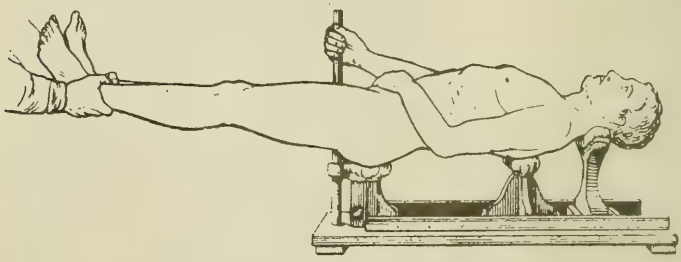


FIG. 61.—Ollier's improvised pelvi-cervical support.

being made fast. To this latter a solid vertical metal rod is fixed which lies between the patient's legs so as to prevent the body from being pulled down when traction is made upon the limb.

The patient is placed upon the support, and the lower limbs are held in a position of abduction by an assistant. The hip is immobilised by means of a T-shaped plaster splint, the horizontal limbs of which surround two-thirds of the circumference of the pelvis, and the vertical, longer portion is moulded to the anterior surface of the limb. Those who are not accustomed to this plaster casing will very likely not look kindly upon it at first sight. It will appear paradoxical. Yet in reality it immobilises very well. The patients like it, and the dressings are much

facilitated. It is very strong, and will serve for a long time; and, finally, it offers the advantage of facilitating the application of continuous extension.

This plaster apparatus is made of eight double thick-

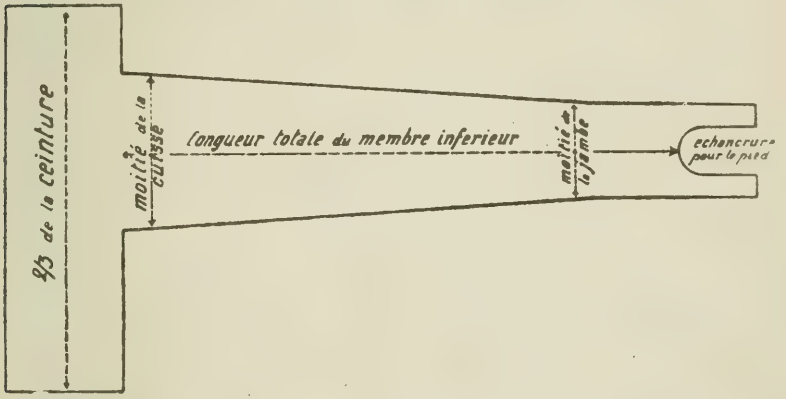



FIG. 62.—T-shaped splint for dorsal pelvi-pedial casing.

nesses of tarlatan in this way: It is T-shaped with unequal horizontal branches. The long vertical branch will be half the circumference of the limb in width, and is cut out at the lower end into a U-shape, the two sides

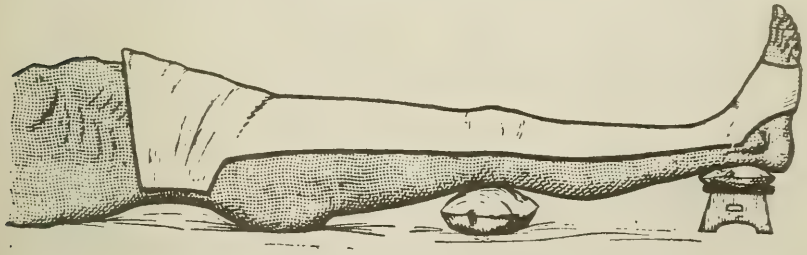


FIG. 63.—Dorsal pelvi-pedial casing for resection of the hip-joint. A bandage fixes the casing firmly to the lower limb and completely immobilises the hip. Continuous extension is possible.

of which are intended to go round the foot. The wide horizontal branch will be a little deeper than the height of the pelvis and will be long enough to go round two-thirds of the pelvic circumference.

Before putting on the plaster, some wool should be placed over the epigastrium, so as not to compress the abdomen, and a gauze bandage is applied to the limb as far as the foot. The apparatus may be made in two pieces, the pelvic portion widely covering and holding in position the crural portion, or, better still, the two parts may be sewn together. The bandage is impregnated with plaster and is moulded to the limb by a few turns of an ordinary bandage, and care is taken to keep the limb in the desired position during the eight or ten minutes that it takes to dry. The patient is put afterwards on a bed, the mattress of which rests on fracture boards. Thanks to this precaution and the use of an air pillow under the buttocks, Bonnet's splint can be dispensed with.

(b) *Later Dressings.*—It is often necessary to renew the dressing the day after the operation, or in the following forty-eight hours. Anæsthesia by chloride of ethyl will facilitate matters greatly. The plaster is reapplied without difficulty. The plugging in the anterior wound need only be changed at the end of five or six days, even later if possible. The posterior drainage tube, if all goes well, should be replaced by a smaller one at the end of twelve days. If the temperature rises, attempts should be made, under anæsthesia if necessary, to see if there are any pockets of pus posteriorly, or retention of discharges within the acetabulum.

If the temperature is raised and drainage appears to be unsatisfactory, continuous extension is indicated. For that purpose, before replacing the plaster, strips of adhesive strapping are applied to the thigh in the form of a stirrup, according to Tillaux's classical extension method. The plaster is then fitted over the limb and traction applied in the ordinary way. If the wound progresses aseptically, few dressings are needed. A cure will be obtained in about two months. It is beneficial to maintain immobilisation

in the abducted position for three months at least; walking will only be permitted when the patient wears a plaster splint surrounding the lower limb. At the end of six months the patient may walk with a raised boot and a stick.

### V. Evacuation of Patients with Hip Wounds

Patients wounded in the hip-joint cannot be moved at first. Those injured by a long-range bullet ought to be kept under observation for a week. At the end of that time they can be evacuated in a plaster splint embracing the lower limb and the pelvis, the wounded thigh being abducted to 25°, and the plaster spica being put on under traction (16 to 21 lb.). The "pelvi-pedial" splint, described above, can also be used. All other cases of wounds of the hip are only to be evacuated after a primary prophylactic operation. They should be kept as long as possible in the front ambulances, evacuated only by short stages, and after a sojourn of at least fifteen days on the spot. The ideal method is to keep them till they are quite well.

The splint for transport which is best for them is the "pelvi-pedial" splint described above. If it is available, the patient is put into a Bonnet's splint, which will make the journey easier. But this journey ought to be as short as possible, and the patient should be set down at the first surgical station (*relai*).

### VI. Treatment of Patients seen late or after Evacuation

1. A Wounded man, picked up some time after being injured, arrives at the Ambulance at the end of 24 or 48 hours.—Such cases are frequent; wounds of the hip are profoundly shocked, are generally incapable of being moved early, and their trans-

port is always difficult, especially in the narrow, winding trenches. Under these conditions the articular wound is practically always infected, and resection of the hip must be performed at once.

The treatment is commenced by cleaning up the wounds of entrance and exit so that any foreign bodies can be removed, and an exact idea gained of the extent of the injuries. One would not be content to diagnose a simple fracture of the trochanter if the wound ran along the inter-trochanteric line. It would always be necessary to remember the possibility of there being separation of the head of the bone by contre-coup, and if radiography is not available, one would try to ascertain the exact condition by clinical examination and surgical exploration.

I lost a patient last year through not having done this: secondary resection was too late to arrest sepsis. On the other hand, I cured by resection a man wounded in the buttock, the head of whose femur had been separated by a bullet which had passed through the trochanter.

After the wounds have been explored and cleared out, the anterior incision should be made, and resection performed according to the technique indicated above. If the neck be found incompletely fractured, it is not necessary to confine oneself to esquillectomy, but typical intra-cervical, pre-trochanteric resection should be done.

Immobilisation should be effected by means of the plaster casing already described and evacuation delayed as long as possible.

2. A WOUNDED MAN ARRIVES AT THE BASE, UNOPERATED UPON, BUT DOING WELL.—This is quite an exceptional occurrence. The missile, which is not markedly septic, usually remains in contact with the head of the bone, which may or may not be fractured. Early intervention is not called for, although the removal of a foreign body is always necessary; the

treatment should be commenced by strict immobilisation for some days. If all goes well, the projectile should be removed at leisure under radioscopy or after precise localisation. Under these circumstances operations on the bone can sometimes be avoided, leaving ankylosis to ensue naturally. If there is any fever, intervention should be undertaken without delay and according to the ascertained nature of the injury.

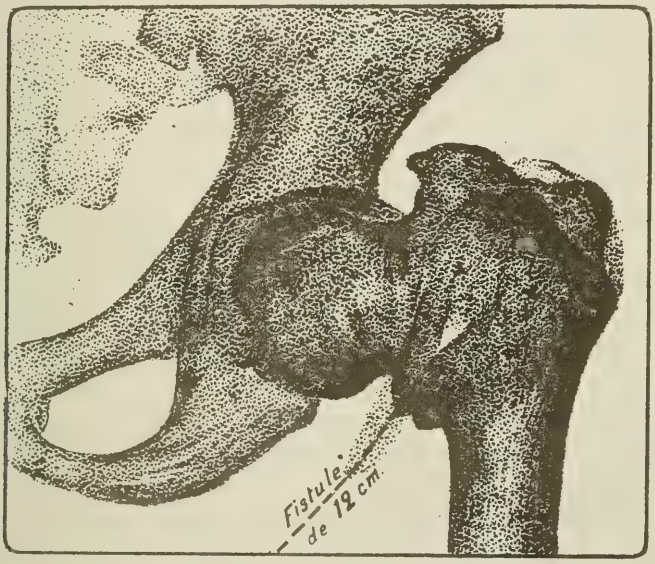



Fig. 64.—Bullet-wound passing through the hip to the buttock in August 1914, a sinus remaining ever since. The hip is ankylosed. Exploration by the wound led to a centre of osteitis behind the trochanter, the sinus terminating in the mass of the adductor muscles 3 inches from the crural fold.

It should be limited to simple drainage after removal of the missile, or resection; the latter is often preferable.

3. A WOUNDED MAN, UNOPERATED UPON, HAS A SUPPURATIVE ARTHRITIS.—Even if there are accompanying visceral injuries (vesical or fæcal fistula), resection of the hip should be performed at once by

the anterior method, the joint lesions being much more important than the visceral wound from the point of view of life. In these cases one will generally find it advisable to apply continuous extension directly after the operation ; it greatly facilitates drainage of the joint.

4. A Wounded man is seen after some delay with a faulty Ankylosis or Sinuses.—(*a*) *When there are one or more sinuses at the hip.*—After radioscopic examination, either a simple curettage or resection will be performed, according to the injury present. There is some advantage in a partial operation like curettage, in not following the fistula but going directly for the bony focus which keeps it up. The sinuses are often very long, and to follow them accurately considerable damage must be done. Instead of this, it will be better to make directly for the point indicated by the radiograph, or by exploration with the probe. In a case of this kind, where a sinus four and a half inches long existed on the internal surface of the thigh in the middle of the adductor muscles, I was able, by making an incision near the trochanter, to come straight upon a centre of osteitis in the neck of the femur.

(*b*) *When the limb is ankylosed in a bad position*, i.e. flexion and adduction, sub-trochanteric osteotomy should be performed at a distance from the seat of the old injury, but not resection.

# CHAPTER VI

## WOUNDS AND FRACTURES OF THE KNEE

### I. Anatomical Types and Clinical Course

PENETRATING wounds of the knee are articular lesions which during the present war have given surgeons the greatest anxiety and have caused them the greatest disappointment. The surprising rapidity with which sepsis, often fatal, develops, and the impossibility of checking it by repeated operations, each being too late, have produced in the mind of the surgeons at the front a profound pessimism ; many have arrived at the conclusion that amputation should be performed at the first appearance of infection, without waiting for arthrotomy or resection—an opinion which is in marked contrast with the optimism of certain surgeons at the base.

Strictly speaking, this pessimism is not justified ; conservative surgery is perfectly suited to the knee-joint, but there is no part of the body where it is more important to choose straight away the right operation suited to any given case. Each operation has very precise indications ; it is of great importance to do only the operation required and to do it early. These indications are based upon an exact knowledge of the several anatomical types of injury, which are as follows :

(*a*) A PUNCTURED WOUND WITH PUNCTIFORM SKIN-OPENINGS.—This is really a puncture of the synovial membrane, accompanied or not by a fracture, generally not comminuted, but always followed by hæmarthrosis.

In spite of the local pyrexia of the first few days and the increase in the size of the knee, these wounds heal readily if the limb is rigidly immobilised, and the knee regains almost normal action after two or three months, except in the case of severe fractures, which lead to ankylosis, or at least to a considerable limitation of movement. Out of 38 cases that I have collected (10 my own, 19 of Gayet, 2 of Delore, 7 of Cotte), I have counted 38 recoveries.

(*b*) SMALL OR MODERATE-SIZED WOUNDS WITH PARIETAL FRACTURE OF THE KNEE AND THE MISSILE IN SITU.—These are the most frequent cases. The wound is very small in appearance; its edges are lacerated and contused; pressure sometimes causes the exudation of viscid blood-stained fluid with small blackish clots. On arrival at the ambulance the injury may appear trifling. An ordinary hæmarthrosis may be diagnosed, and the existence of penetration of the joint only suspected from the distension of the synovial membrane, which is not a diagnostic sign, and has no absolute importance, because foreign bodies in contact with it, but outside the joint, often give rise to a voluminous hæmarthrosis.* If one rests satisfied with that opinion, on the second day symptoms of sepsis appear and generally develop rapidly, until death occurs after a short interval.

This dangerous condition is due: (1) to the presence in the joint of septic particles of clothing, earth, chalk, etc., causing acute arthritis; (2) to the existence of fissures more or less prolonged into the shafts of the femur or tibia, whence arises a formidable osteomyelitis. Unless there is intervention, death ensues in two-thirds of the cases from gas gangrene, or some-

* These are the cases that lead certain surgeons to believe that a number of wounds of the knee caused by shell-fragments can be cured by immobilisation, aspiration, or the application of ice. These non-penetrating wounds of the knee are like non-penetrating wounds of the abdomen, and they should not be taken into account in speaking of the real gravity of wounds of joints.

times from articular septicæmia. Generally the symptoms of sepsis force us to act, and the following is the course of events : After two days of immobilisation in a splint, the patient being feverish and in a poor general condition, arthrotomy is performed to drain the joint. The septic condition continues, and two days later fresh drainage tubes are inserted alongside those already inserted. Sometimes an incision is made in the popliteal space to obtain better drainage, but that does not stop the infection ; the face becomes livid, the patient looks ill, and the general condition is profoundly affected. A resection is then performed, while the temperature is still high, but it is followed by no remission of the symptoms : pockets of pus form at the back of the thigh and leg and phlebitis may occur. Amputation is finally decided upon, but it is too late, and the patient dies soon after. The whole course of the case has occupied a fortnight or three weeks. Here is a typical example that I came across in a patient treated at the front and arriving in my wards in a pretty bad state.

C. J. was wounded on April 8th by a shell-splinter in the right leg and knee and the left leg. On the right side there was a fracture of the tibia. Intervention was not considered necessary, the patient being in a state of shock, and the two lower limbs were immobilised and antiseptic dressings applied. Four days later, on account of severe symptoms of infection, the fracture of the right leg was explored ; fragments were removed, a solution of iodoform in ether was injected into the wound, and the knee explored. The wound did not appear to communicate with the joint ; the hæmarthrosis was relieved by puncture and the limb immobilised in a plaster casing. In the left leg there was an infected fracture of the fibula and some sloughing muscular tissue, to which the general symptoms were attributed ; the limb was amputated at the seat of election. In spite of this the general

condition remained grave, the temperature reached 39·6° C. (103° F.), and, on the 17th, arthrotomy of the right knee was performed and a quantity of pus let out. On the 21st, the temperature being 40° C. (104° F.) and the pulse 130, the right thigh was amputated. On examination of the limb (as the medical case sheet which accompanies the patient says), a purulent arthritis is found with wads of clothing, a wound of the external condyle, and a fissure of the tibia extending right through the head. Then the patient was evacuated to the base three weeks after his injuries, his general condition being fair: it is certain that early intervention would have avoided the double amputation.

At other times, in an apparently favourable case, death occurs from chronic septicæmia, taking about two months; at the autopsy, abscesses are found at the back of the leg and thigh communicating with the joint, and there are miliary abscesses in the lungs, kidneys, liver, and spleen. At the outbreak of the war these cases were so frequent that for many surgeons there was only one treatment for injuries of the knee—amputation of the thigh at the first sign of sepsis.

It was on this account that, in June 1915, Tuffier wrote that he was appalled at the number of amputations of the thigh consequent upon injuries of the knee. From what I have seen at medical boards, two-thirds, if not more, of the amputations in the thigh have been done for wounds of the knee. Must it be said, then, that these wounds are beyond the resources of surgery? Most certainly not! Wounds of the knee only take this lamentable course if the decision to operate is not taken promptly; the majority of those that are suitably operated upon in time, run a perfectly simple course; but to operate successfully it is necessary to recognise that, independently of the muscular and synovial injury, there are often superficial cracks, crush-fractures or fissures in the bones,

and that a missile and the fragments of clothing in contact with it may cause these fractures to become gravely complicated. However mild the appearance may be at the outset, if a missile has penetrated the joint, there is every reason for the gravest apprehension.

(*c*) FRACTURES OF THE FEMUR, TIBIA, OR PATELLA.—In these cases the projectile, shell- or bomb-splinter, penetrates a condyle without fissuring the bone (a frequent type), crushes the cancellous tissue of the tibia, or smashes the patella. Sometimes, but less often, a double fracture of the femur and tibia, or a T-shaped fracture of the femur, is found. In other cases a short-range bullet has smashed the whole or part of the articular ends. There are rarely many bony fragments, at least in my experience, while fissures radiating down the shaft are frequently found.

The occurrence of acute septic infection is more constant and more formidable in these cases than in the preceding ones. If the patient is not carried off by acute septicæmia, he is liable to suppurative arthritis, to deep, diffuse cellulitis of the thigh, and to secondary hæmorrhage from the popliteal. In short, if intervention is not practised at once, amputation soon becomes necessary, and only too often it is unavoidable to save the patient's life.

(*d*) DESTRUCTION OF THE KNEE.—In a number of cases, not only are the articular extremities completely crushed, but there is also considerable damage to the shaft of the bone, and fissures extend far down the length of the femur or the tibia. In these cases the vessels and nerves are usually damaged ; infection occurs early in the necrosed tissues, and in the course of the first twenty-four hours gangrene develops with the formation of gas and fœtid sloughs, if not true gas gangrene. There is immediate and considerable shock, which does not pass off ; the mucous membranes

are pale, the pulse becomes thready, the breathing superficial, and the skin cold and clammy.

In short, apart from the first type of injuries, wounds of the knee are of extreme gravity if they are left untreated in the first few hours. If one waits for the indications of sepsis before coming to a decision, one is always a day or an operation behind-hand. It is necessary to act at once, and to be beforehand with whatever may be happening.

### II. Primary Therapeutic Indications

There are four methods of treatment, each with its own indications :

1. **Immobilisation, with or without Aspiration.**— Rigid immobilisation of the knee, with aspiration if there is abundant hæmarthrosis, is suitable for bullet wounds with punctiform openings, but for these only. Doubtless cases of shell-splinter wounds could be cited in which this simple treatment has been sufficient to obtain a cure, but these are, and can only be, exceptions. Besides, among the cases reported are some which are really only parietal, non-penetrating wounds ; and in many others secondary removal of the missile has become ultimately necessary. Simple immobilisation then should be reserved for long-range bullet-wounds.

After careful examination, if it is a case of bullet-wound, and if the skin wounds are both very inconsiderable, an aseptic dressing should be applied with pressure, without operation, and a posterior plaster splint applied from the middle of the thigh to the end of the foot. If the effusion is abundant and painful, the synovial membrane may be punctured if time can be spared, for it is not absolutely necessary ; in any case, it should be a simple aspiration. It is needless to inject ether or any other antiseptic into the joint, and as a rule there is no occasion to repeat the puncture.

Rest will suffice to bring about a cure.

2. **Arthrotomy.**—There are all sorts of methods of arthrotomy of the knee.

*The classical operation* is done by two incisions near the patella, which are often made too small, through which one or two drainage tubes are passed crosswise, above, below, or behind the patella.

*Ollier's arthrotomy*, which is little known outside the Lyons school, comprises four and sometimes even five incisions, two antero-lateral, each about four inches long, one on each side of the patella, extending high and low enough to drain the anterior cul-de-sac above and below the patella ; and two postero-lateral incisions, $1\frac{1}{2}$ in. long, passing, one in front of the tendon of the biceps, and the other between the inner hamstrings. The attachments of the lateral ligaments are divided to the requisite degree, and then between the two incisions on the same side a drainage tube is passed into the joint and under the synovial membrane, but not between the bones. If necessary, a fifth, posterior, incision is made in the popliteal space between the condyles.

*Jaboulay's arthrotomy* is a simple incision of the supra-patellar pouch : the foot is raised considerably, so that drainage of the synovial cavity is made from its lowest point.

*Anterior transverse arthrotomy.*—This was described by Ollier but little employed before the present war. In it the knee is widely opened by means of a curved incision, convex downwards, cutting through the ligamentum patellæ. It was recommended by Quénu at the beginning of the war, and gives free access to the joint. This operation has sometimes to be supplemented by excision of the patella.

Which method should be chosen ?

It is impossible to answer this question in a few words, for these cases are complex ; but the point to insist on is that all these methods are of little use if

arthrotomy is regarded as simply an operation for drainage. In war-wounds arthrotomy should be regarded as essentially an exploratory incision, the first stage in an operation of discovery and trimming up, and not, as it has often been called, an operation for drainage. When once the foreign bodies have been removed and the joint has been cleared out, the simplest drainage incision is the best ; if, on the contrary, foreign bodies are left behind, the most elaborate arthrotomy is only too often inefficient.

Missiles left in the knee after arthrotomy for drainage have undoubtedly in some cases been well tolerated, but these are quite exceptional. As a rule, the early ablation of missiles and infective débris is essential for rapid and satisfactory recovery ; it is absolutely necessary to remove at the earliest possible moment every intra-articular missile. It is for want of understanding of this fundamental principle that so many surgeons at the front have given up arthrotomy.

If we lay down this principle, it may be said that an exploratory arthrotomy is the first step in the treatment of every wound of the knee.

How should it be done ?

(*a*) EXPLORATION OF THE WOUND OF ENTRY.— In view of the uncertainty of the diagnosis in the first few hours, and especially when radiography is not available, it is well to begin by making the incision at the wound of entry, even if it be at some distance from the joint, and to follow it up and retract its edges . As Gayet has justly remarked, this method of exploring sometimes shows that the joint has not been opened ; and, by dissecting carefully, one may be able to extract a missile situated outside the joint, though the latter is full of fluid.

I have always proceeded in this manner and have found it satisfactory.

(*b*) THE MISSILE LIES IN THE OPENING IN THE

SYNOVIAL MEMBRANE.—If the dissection leads to an opening in the synovial membrane, the diagnosis is certain: in that case it is necessary to enlarge the small opening freely but with care, and see if the missile is there. If it is seen, or felt, it is removed along with any fragments of clothing, the opening in the synovial membrane being enlarged at the same time so as to enable the surgeon to explore and clear out the joint. Generally there is no need to do more.

After carefully arresting the bleeding from the synovial vessels, which always bleed freely, the interior of the joint is dried by gauze, and the incision plugged without draining the synovial membrane, or, better still, when the patient can be kept under observation for eight or ten days, the

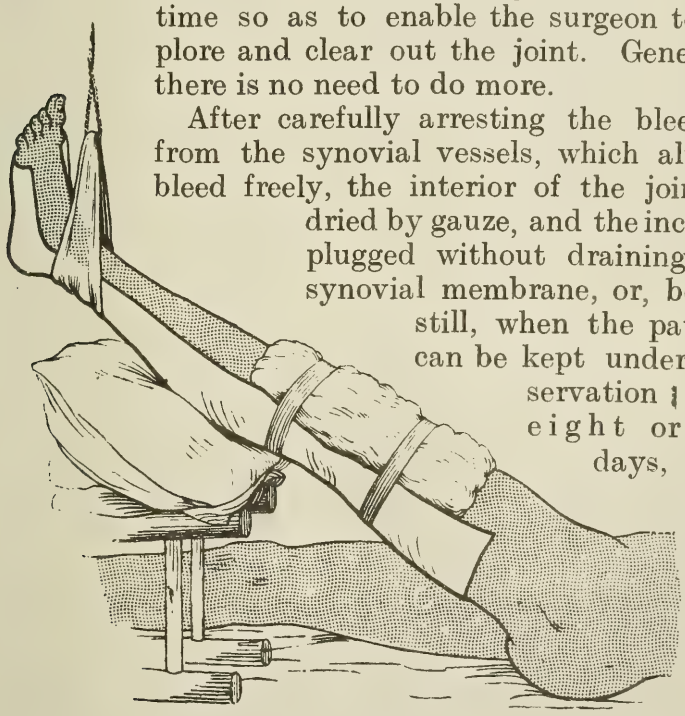


FIG. 65.—Elevated position of the knee after opening the superior synovial cul-de-sac of the knee-joint.

edges of the synovial membrane are excised, and the joint closed with catgut sutures, as Delore has advised.

Exploratory arthrotomy followed by complete suturing of the synovial membrane, which Delore and Kocher have described, is certainly the method of choice in cases that are seen early. But it should

only be used when it is possible to render the parts clean and when nothing suspicious is left behind in the wound or is met with during the operation. The more it is tried and the more rapid the operation, the more often will it be used, and the more perfect the results. If the joint is full of blood, the same method will be employed ; but if the character of the effusion is at all suspicious, it is more prudent to drain the supra-patellar pouch by Jaboulay's method. The cul-de-sac is made to project by means of forceps, which are cut down upon, and a drainage tube is inserted, flush with the joint. The dressing is completed and the foot is well raised, a posterior plaster splint immobilising the joint. The limb is supported on pillows, so that it is at an angle of 45° with the trunk.

(*c*) THE MISSILE IS LOST IN THE JOINT.—It is essential to be able to explore all the recesses of the synovial membrane, so that nothing suspicious may escape detection and removal. The only efficient method for this purpose is to open the knee by the curved subpatellar incision with its convexity downwards. Without troubling about the incision already made in order to follow the track of the missile outside the joint, the ligamentum patellæ and the pad of fatty tissue are divided transversely. The flap containing the patella is firmly seized in catch forceps, and the leg is flexed on the thigh so that the cavity of the joint can be thoroughly examined. After removing any foreign bodies, mopping out the synovial membrane, and arresting all hæmorrhage, the surgeon closes the joint with three layers of sutures—serous, tendino-aponeurotic, and cutaneous. If there is a slight injury to the bone, the synovial suturing should be so arranged as to exclude it from the joint cavity. The tendon of the patella is carefully united, and the wound of entry and the track of the missile are thoroughly excised, left open, and drained with gauze.

If it is thought well to drain the joint, this may be done through the supra-patellar pouch, and the limb well elevated. If the missile is not found, lateral drainage should be effected, and the foreign body localised and removed as quickly as possible later.

(*d*) THERE IS A PARIETAL INJURY OF THE BONE.—This condition is not always very simple : when the joint has been freely opened, parietal injuries, such as small scales of bone chipped off the femur, crushing of the articular surface of the tibia (often with destruction of its cartilage or jagged fissures of the patella), may be found. Frequently the missile is still in contact with the broken bone, in which it has made a sort of cavity for itself. In this case the fragments ought to be removed, and the bone carefully curetted : a strand of aseptic gauze is left against the bone, issuing from one of the lateral incisions, as after an ordinary arthrotomy.

If the operation is performed early and properly, these arthrotomies for extraction of missiles run a favourable course, and the wounds heal by first intention with more or less perfect recovery of movement ; but it is clear that such a method is one applicable only to wounds seen early before any sign of septic infection is present. If such exists, or if there is any doubt about it, it is best to insert drains in the lateral incisions, in case of need converting the curvilinear incision into the H-shaped incision of resection. But the ideal method is to intervene soon enough, and with sufficient attention to detail, so that the above-indicated measures may be possible.

I have collected notes of 58 cases of early extraction of splinters in the knee joint with 58 recoveries (5 my own, 6 Delore, 5 Gayet, 6 Tisserand, 14 Santy, 10 Bosquette, 1 Desplas, 11 Sencert). One of my personal cases is the more striking as there was a penetrating wound of both knees with a double cancellous fracture of the upper surface of the tibia. The patient

recovered without complications, and with extensive movements of both limbs. This result is 11 months old.

(*e*) THE MISSILE HAS PENETRATED THE POPLITEAL SPACE FROM BEFORE BACKWARDS.—The condition is not rare, and sometimes injuries of vessels or nerves accompany the joint wound. After arthrotomy, only a posterior perforation of the synovial membrane is found. Generally in these wounds, action is confined simply to draining the joint, leaving the missile alone, unless amputation is done for injury to the vessels.

Theoretically it would appear preferable to close the arthrotomy wound, leaving a drainage tube in the supra-patellar pouch, and to expose the vessels and nerves and the missile, which has been localised by radioscopy, through an incision in the popliteal space. Another method would be to divide the crucial ligaments, when, with the perforation in the synovial membrane as a guide, the missile could be sought for in the popliteal space from before backwards.

I have not seen any case of this kind, but it seems to me that I should prefer the popliteal method, since division of the crucial ligaments leads to dislocation of the knee, which is dangerous from the point of view of the ultimate usefulness of the joint.

3. **Resection of the Knee and Ablation of the Patella.**—When there is evident fracture, or when exploratory arthrotomy has revealed extensive injuries to the bone, removal of the missile and foreign bodies, preventive drainage, and simple esquillectomy do not suffice. In order to save the patient's life and to safeguard the functional usefulness of the limb, it becomes necessary to perform a primary resection.

This needs proof.

There can be no longer any doubt about the necessity of bone-operations in these cases: the gravity of the sepsis which occurs at the seat of fracture is such, that all surgeons who at the outset had preconceived

ideas on the subject have been quickly converted to free esquillectomy and clearing; but many are unwilling to consider the future orthopædic result (Potherat, Picqué). The surgery of the bones, however, does not date from the present war, before which it was known that atypical resections give poor results, that removal of the condyle may lead to troublesome malposition of the leg, and that to obtain a good ankylosis, two bony surfaces which have been freshly made, not a cartilaginous surface and a recent section of bone, must be placed in contact. Some surgeons have said that union between bone and cartilage has occurred. But this is only apparent, because the cartilage has disappeared in consequence of infiammation, which has therefore done, after much pain and danger, what one cut of the saw would have done at once, simply and without risk.

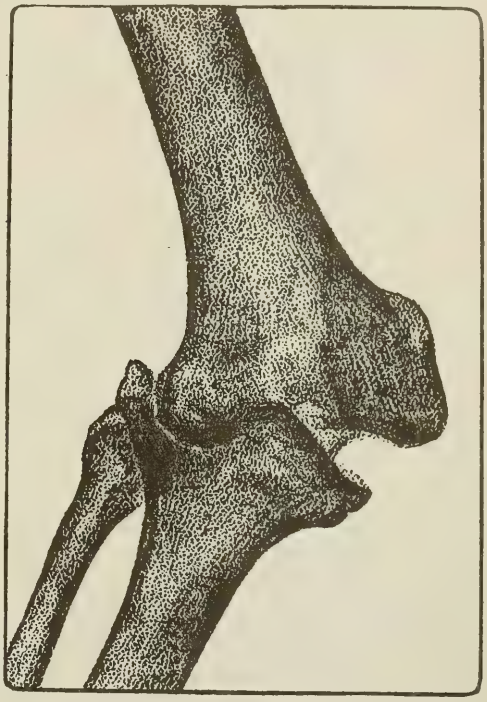


FIG. 66.—Considerable and progressive genu valgum following esquillectomy of the head of the tibia performed at the front. The joint having suppurated, a vicious ankylosis has been obtained with difficulty at the end of nine months. Walking was impossible; orthopædic resection of the knee was necessary and gave a good result. It would have been more simple to perform a typical resection at the outset.

In good bone-surgery it is absolutely contra-indicated to perform, on the ground of economy, what, orthopædically speaking, are illogical operations; the economical surgery is not that which sacrifices least bone, but that which gives the maximum result in a minimum of time and risk. At the knee, typical resection alone fulfils these conditions.

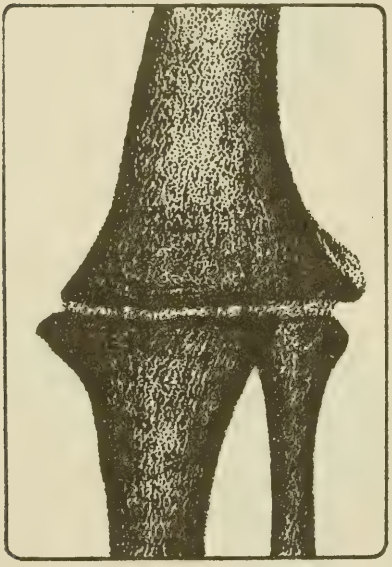


Fig. 67.—Ankylosis after typical resection of the knee for fracture of one condyle caused by shell-splinter.

If the patella is comminuted, the whole of it should be removed subperiosteally; esquillectomy is not sufficient. If the femur, or the tibia, or both, are involved, the classical operation of resection of both bones should be performed by removing the patella and making the section through the epiphyses if possible. In no case should it be limited to the ablation of one condyle, or to resection of the tibia only.

Done early, typical resection gives excellent results, as Viannay was the first to show. I have collected 37 cases (7 of the patella and 30 of the femur and tibia) more or less early (of which 3 cases were my own), with 36 recoveries and 1 death.

One can say, then, that all non-parietal fractures of one or other bone of the knee when the vessels and nerves are intact should be treated by primary resection of the patella or of the femur and tibia.

4. **Amputation.**—Primary amputation at the very outset is called for in bony injuries which are so exten-

sive that resection is impossible or dangerous. When, for example, the condyles and the shaft of the femur are split up, when there are fragments as high up as the middle of the bone, which is not rare and necessitates in consequence a sacrifice of over five inches of its length, the indication to amputate is undoubted, because the risks of infection with so much loss of substance are too considerable, and in addition the only possible result must be deplorable from an orthopædic point of view.

Similarly, when there are injuries of the vessels and nerves, resection is a gamble ; immediate amputation is called for. Functionally it is incumbent on the surgeon to obtain a stump which is solid and free from pain. If there is no hope of giving the patient a leg capable of carrying the weight of his body, the loss of the limb is a necessity which cannot be avoided.

The prognosis of these amputations is, as a matter of fact, always grave : the patient, who is in a state of severe shock, affords the surgeon only the choice between interfering at once and seeing him die of shock, or waiting to see him die of sepsis.

In principle, it is better to interfere at once, after having tried to stimulate the patient before a good fire, and in a warm bed, with large doses of camphorated oil. It has often appeared to me that morphine would do much to improve the condition. Preoperative transfusion, where possible, is the heroic remedy for these cases of severe shocks.

To tabulate the foregoing : for articular bullet wounds, simple immobilisation is suitable ; for foreign bodies in the joint, arthrotomy and immediate extraction ; for parietal fractures, primary esquillectomy ; for smashed patella, early excision of that bone ; for fractures destroying the statics of the joint, typical resection ; for extensive crushing with lesions of the vessels, amputation.

### III. Operative Technique

For the surgery of the knee, lumbar anæsthesia by novocaine-adrenalin is an excellent method; in cases of shock, and of crushed joints, it should certainly be the method selected whenever it is possible to employ it.

The directions given above for the performance of a primary arthrotomy in different cases suffice for the performance of that operation. I will only add that the semi-lunar cartilages ought always to be preserved if they are intact, and that under no circumstances should the crucial ligaments be cut. Having said that, nothing further remains but to deal with resection.

FIG. 68. — H-shaped incision of typical resection.

This should be performed in accordance with the classical directions of Ollier for a typical resection carried out in healthy tissues, with a sharp rugine, carefully sparing the periosteum.

It is done in the following manner:

(*a*) *Incisions.*—Following a previous transverse exploratory arthrotomy, as it often does, resection will always be performed by an H-shaped incision made when the knee is flexed. The transverse branch of the incision does not go beyond the lateral ligaments, but is long enough to permit the condyles of the femur to be dislocated through it. From the ends of that incision, which is three and a half inches long, two vertical incisions are made, the greater part of each of which is above the horizontal line, at either side of the patella.

(*b*) *Removal of the fractured Bone.*—When the injuries have been well exposed, and the clots removed, any large fragments of the femur or the tibia which are

more or less movable are stripped of their periosteum with the cutting rugine after they have been fixed with forceps. This renders it easy to preserve their entire periosteal covering, which is very useful for the after-consolidation of the limb.

After the extensive damage done by the missile has been cleared away, all small free splinters are removed in a similar manner, and it is only when this process of clearing out the damaged area has been completed that the articular operation is proceeded with.

(*c*) *Removal of the Patella.*—The patella should be removed with the rugine, as it is more troublesome than useful in an ankylosed knee; the culs-de-sac around it are dangerous recesses, from the point of view of sepsis. Sub-periosteal removal of the bone leaves clean and smooth surfaces and sound tendon and periosteum, which will give a good anterior covering to the ankylosis.

(*d*) *Excision of the Synovial Membrane.*—Excision of the synovial membrane is then performed as completely as possible with forceps and scissors. The supra-patellar pouch is dissected out very carefully, so as to remove the whole of the large sac and the synovial pockets from which septic absorption might otherwise take place; the lateral prolongations over the sides of the upper end of the tibia are similarly treated. The posterior ligament of the joint is stripped and identified with great care, and the state of the vessels examined through this structure.

(*e*) *Section of the Bones.*—After all the normal as well as the damaged structures of the joint have been removed, there remains an irregular roughened end to the femur which is only in limited contact with the tibial surface, if at all. The end of the femur is removed with the saw, without taking any notice of fissures which may run up the shaft of the bone; then the cartilaginous surface of the tibia is removed in the form of a thin layer.

(*f*) *Fixation of the Femur and Tibia.*—This is not absolutely necessary; simple juxtaposition of the femur, by pushing it against the cancellous tissues of the tibia, as Viannay does, apparently suffices to ensure bony union. However, if the operative conditions are favourable, and if one can count upon the absence of sepsis, there is every advantage in inserting a metal suture, two hooks for example, as L. Berard recommends. The operator must see that his assistant keeps the limb in good position while the hooks are being inserted, or while the dressing is being done.

(*g*) *Sutures.*—When there is extensive loss of bone, the soft parts are redundant and form cavities around the bones, which should be lightly packed with aseptic gauze, whilst a drainage tube is inserted on either side opposite the line of junction of the bones, at right angles to the long axis of the limb. The tendon of the patella and the soft parts covering the front and sides of the joint are accurately united with catgut sutures. Cutaneous sutures should be inserted in front only; it will be well to put in none in the region of the wound made by the missile, and simply to insert some gauze between the edges of the skin wound. This avoids infection of the cellular tissue and the formation of pockets of pus around the joint, while the healing process is much accelerated.

## IV. Post-Operative Treatment

1. **After Arthrotomy.**—Whatever may be the extent of the operation performed, the knee, under a dressing of aseptic gauze, is immobilised in a posterior moulded plaster splint of the usual type, extending half round the circumference of the limb, and from the middle of the thigh to the end of the foot.

The limb is raised on pillows and kept elevated by a figure-of-eight bandage round the instep, fastened to

something above the bed, such as a screw in the ceiling, or a bar above the bed.

After an arthrotomy where sutures without drainage have been used, the first dressing should be delayed as long as possible if all goes well; towards the seventh day the stitches and any gauze along the track of the missile are taken out. If drainage has been used, one can wait several days. Gayet recommends the twelfth day and advises that elevation of the limb should be continued until the wound has closed. As a general rule, the less one touches the dressing the better.

Towards the fifteenth day, gentle movements are commenced by making the patient perform small active movements of the quadriceps, and by massaging the limb. This should be continued each day, without attempting any movement by instrumental or mechanical means. Walking is allowed at the end of three weeks, if the movements have produced no reaction in the joint. During the first week the patient wears a dressing that exerts pressure on the joint, preventing movement of the knee when walking, but he will be allowed to walk with his knee free in a month.

If there has been injury to the bone or the vessels, immobilisation will be kept up for a month.

2. **After Resection.**—Immobilisation has considerable influence upon the favourable post-operative progress of patients who have undergone resection, especially if the bones have not been fixed together by metal hooks.

In a resection running an aseptic course the question is simple, but often, when there is free oozing from the wound, it is impossible to procure permanent immobilisation during the first few days. The best way is to use for that period the classical posterior moulded plaster splint, provided with an impermeable lining in the middle, and put on while the patient is still under the anæsthetic; or even, paradoxical as it

may appear, an anterior splint of the same material, embracing half the circumference of the limb from the top of the thigh to the foot. This is perhaps the best method of securing temporary immobilisation, for the plaster casing is easy to take off without moving

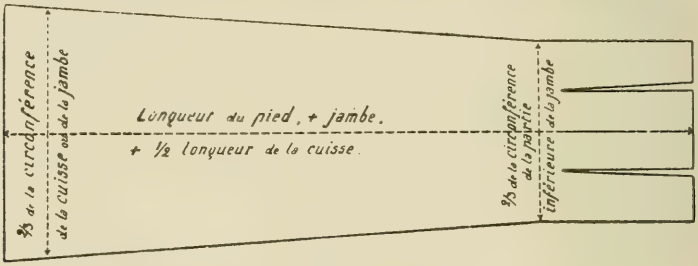

⅔ de la circonférence de la cuisse et de la jambe
Longueur du pied, + jambe.
+ ½ longueur de la cuisse.
⅔ de la circonférence de la partie inférieure de la jambe

FIG. 69.

the limb, while it renders it quite immovable, and does not become softened as does the posterior splint (see fig. 63). A large and rather wide wooden splint, slightly hollowed out in the middle, with a foot-piece, like Bœckel's splint, reaching as high as the middle of the thigh, may be used: this is provided with an

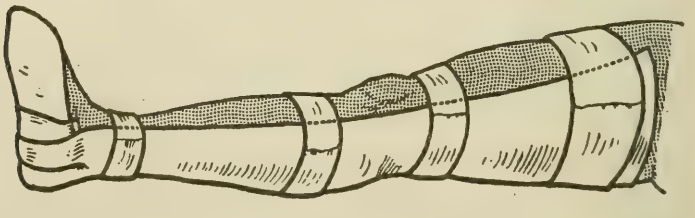


FIG. 70.—Grooved leg-splint for transport of cases of wounds of the knee and of the tibio-tarsal joint.

impermeable covering at its middle and is fastened on with the bandages.

The dressing should be left untouched as long as possible, especially when the general condition of the patient is good. Generally it is necessary to change the superficial layers on the third or fourth day. It

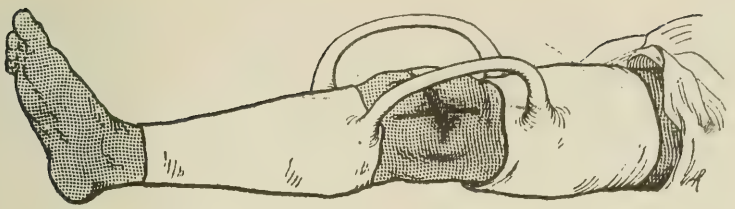


FIG. 71.—Interrupted splint which should never be used after resection, because the ends of the bones are not properly immobilised and backward displacement of the tibia may ensue. This casing should only be used after arthrotomy, and only then when the lateral ligaments have not been destroyed.

is well to change the deeper ones a little later. Permanent immobilisation may sometimes be effected as early as the eighth day. If the wound remains aseptic, the simple posterior gutter splint is the best appliance for this purpose, but sometimes the wound oozes a great deal, and then the splint gets constantly wet, and softens so that it no longer immobilises the limb, and has to be renewed frequently. The interrupted plaster appliance seen in fig. 71 is then a tempting form of splint to use, but in the knee it has great drawbacks: if used before the soft parts have shrunk, the plaster bandages immobilise badly and the popliteal space is not supported. A disastrous backward displacement of the tibia occurs, and the resulting ankylosis is bad (fig. 72). The interrupted splint therefore must not be used too

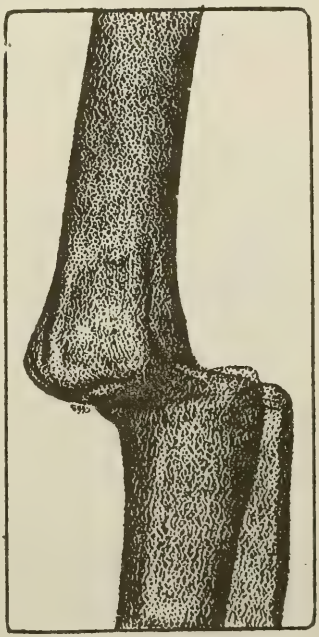


FIG. 72.—Bayonet-shaped ankylosis following immobilisation in an interrupted splint without a posterior support.

early : if possible, a fortnight at least should elapse before it is applied. If it is necessary to apply it sooner, it must not be forgotten that the apparatus is only temporary ; further, a small posterior splint must always be added to the circular plaster casing round the thigh and the leg, so as to maintain the bones in position. Lastly, it is necessary that the plaster should envelop the foot, so that the tibia can be fixed. These patients do better when the leg is raised a little ; and an appliance with supports below should accordingly be chosen.

These remarks will show that it is very difficult to get an apparatus which prevents the knee from moving, which is all-important.

The steps of the procedure are as follows :

The lower limb is firmly immobilised in extension by a reliable assistant, the patient being drawn to the edge of the table, and the assistant standing between his thighs. A large towel is then passed under the knee, which is covered with a small aseptic dressing without any cotton wool. The towel supports the limb during the application of the first part of the plaster.

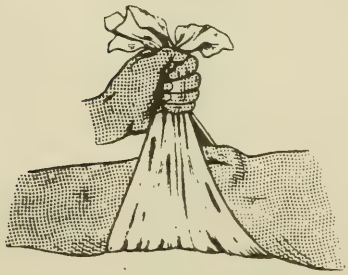


FIG. 73.—Method of holding the knee during the application of the plaster. An assistant supports the heel at the same time.

This comprises :

(1) A plaster bandage encircling the thigh from the upper third as far down as the dressing at the knee, and reaching lower behind than in front.

(2) A plaster bandage encircling the leg, extending higher behind in the popliteal space than in front (where it reaches the tubercle of the tibia), and covering the heel. The foot is kept at a right angle with the leg.

(3) Two iron rests made as seen in fig. 74 : the vertical limbs below the knee are higher than those above it, so that the limb is slightly inclined upwards towards the foot. These rests are incorporated in the plaster bandage, so as to form two lateral supports, inclined a little outwards.

(4) A small posterior plaster splint, of the width of the hand, applied over the popliteal space between

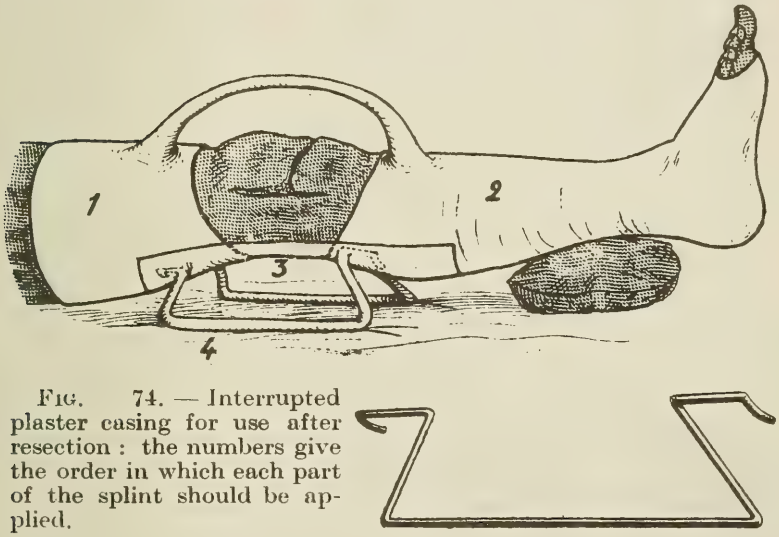



FIG. 74. — Interrupted plaster casing for use after resection : the numbers give the order in which each part of the splint should be applied.

the two circular portions of the apparatus, with which it will be incorporated.

(5) Another bracket can be incorporated at the middle of the upper surface so as to bridge over the knee from below upwards, if it appears useful : it is not generally used.

When the splint has been completed, the edges of the central gap can be cut away as required, and the anterior parts of the foot and instep are exposed. The plaster cast thus made cannot, and ought not, to be kept on the limb until the end of the case. At the end of a certain time it will allow some play, and the leg will be too free ; immobilisation is no longer

satisfactory, and displacement, though late, is still possible. This must be watched for, and there must be no hesitation in applying a fresh apparatus.

When is it necessary to remove the gauze drains for the first time? The drainage tubes can usually be removed towards the sixth day, while the gauze is left in position and moistened with a saline solution. Towards the eighth day this gauze is drawn out little by little; towards the tenth day it is completely removed and replaced by fresh gauze, either soaked in saline solution, or dry, according to the condition of the wound. Insolation and hot air treatment are now commenced. If everything goes on well, the dressing can be postponed for a still longer period, and fifteen days may elapse before it is renewed.

If there is the least rise of temperature towards the tenth or twelfth day, the occurrence of an abscess must be suspected: this is usually found in the calf.

Consolidation of the limb generally requires three months, but walking should not be allowed before four months, and even then only after the application of a plaster bandage thoroughly immobilising the knee.

After consolidation, a leather covering, moulded to the limb, with lateral metal supports, should be worn for a year, for fear of secondary deflection of the knee.

3. **After Ablation of the Patella.**—The course will almost always be favourable. The first dressing will be delayed as long as possible, up to the eighth or tenth day. Movements are commenced as soon as cicatrisation is complete, that is to say about the end of three weeks or a month. Improvement is rapid, and as early as the second month the result will be very satisfactory: extension normal, flexion half the normal.

### V. Evacuation of Patients with Knee Wounds

No one with a wound of the knee (except with the simple perforating bullet wound) ought to be evacuated without surgical exploration.

If this has allowed of easy extraction of a missile, the patient may be evacuated at the end of five or six days in a plaster casing, if it is really necessary, but it is better to keep him twelve days.

If there has been a free arthrotomy, evacuation should be delayed until the twelfth day. A patient who has undergone resection ought to be kept as long as possible, at the least fifteen days if all goes well. As a rule, only cases which have had a normal temperature for several days, and in which there is not much oozing, should be evacuated.

For evacuation, the limb should always be immobilised in a plaster casing. If an interrupted plaster splint has not yet been applied, the posterior half-gutter or the large pelvi-pedial splint is the best apparatus for transport.

The journey should not exceed twenty-four hours in duration, and it would be better not to exceed twelve hours.

### VI. Treatment of Patients seen late or after Evacuation

The patient, correctly operated upon by arthrotomy or early resection, generally recovers uneventfully.

It is quite different with those who have been operated on insufficiently or not at all. There are no fractures met with in war that are more difficult to treat in the secondary stages.

Let us take first those who have not been operated upon.

1. *A patient arrives on the second or third day after the injury with an acute suppurative arthritis of the knee.* What should be done?

(*a*) After determining by radiography, if possible, the presence and the exact position of a foreign body and the absence of a fracture, the orifice of entry is freely incised down to the synovial membrane: arthrotomy is then done by a vertical incision, four inches long, on each side of the patella. Through these one can generally extract any foreign body and the missile. Then two postero-lateral incisions are made for drainage; in some cases (*e.g.* missiles at the back of the joint, swelling, popliteal œdema and pain) an incision into the post-condylar cul-de-sac is made through the popliteal space. But the risks of popliteal drainage must not be forgotten. Many patients treated in that way have died of secondary hæmorrhage. The popliteal incision ought only to be an incision to facilitate search for the missile, and not one for drainage. To establish this latter, incision of the supra-patellar pouch with the foot elevated is the best method. A drainage tube should be placed in each opening in the synovial membrane to keep it from closing, but it is not necessary to push the tubes deep into the cavity of the joint, and still less so to make them pass right through it. The serous membranes tolerate these foreign bodies very badly; often, after drainage thus effected, the temperature is only reduced by doing away with all the drainage tubes. No transverse tubes, therefore, should be used.

If at the end of two or three days this drainage has not arrested the sepsis and brought down the temperature, amputation through the lower third of the thigh should be performed at once before the patient has gone too far downhill. It should be done by the circular method, with or without lateral incisions, and no sutures should be inserted. The muscles are profoundly septic, infiltrated and œdematous; in order to expose the tissues, the flaps should be temporarily turned back, for the least retention of discharges is very dangerous.

Perhaps some of these cases of arthritis might be amenable to excision of the synovial membrane. It might be tried. I do not dare to recommend it, not having had any experience of it.

(*b*) If a fracture, however limited, exists, resection of the knee should be performed at once; the danger arises as much from osteomyelitis as from arthritis, if not more. And, as Poncet taught, the chances of saving the limb are improved in proportion to the nearness of the time chosen for resection to the onset of the infection.

In these cases, drainage of the joint is absolutely without effect; any exceptions that can be cited do not invalidate the general rule.

It is necessary, then, to treat these cases of articular osteitis at the outset by resection of the knee. It is often said, in connection with these wounds, that arthrotomy, resection, and amputation ought to be done, one after the other, when a primary operation does not succeed in presenting the onset of infection. There is no conception more illogical or more dangerous. Successive operations are always too late: it is most important to choose at the outset the best method of intervention, and for septic fractures of the knee, the only good one is resection, done as early as possible. Resection ought not to follow arthrotomy: it ought to be preferred to it whenever there are injuries to bone. It should even be employed when there are only simple injuries to the cartilage (erosions or necrotic ulcerations).

L. Berard has shown cases that are very instructive from this point of view, and with Tuffier, Quenu, Viannay, and Gayet, he has reported cases favourable to early secondary resection.

But it must be recognised, as all those who have recommended it have said, that (intra-febrile) secondary resection is far from giving uniform results: it only succeeds if it is performed early, for injuries

which are not too extensive, before medullary infection has occurred, and when the damage to the soft parts is not too great. Indeed, it is only justified when it does away completely with the area of the bone-sepsis. Contrary to what has often been said, it is by no means the most effectual form of articular drainage : so far from being that, it does not drain at all.

If time is lost in performing it, it is a great gamble, and immediate amputation ought to be preferred to such dangerous ultra-conservative treatment. In any case, if resection is not followed by a rapid fall of temperature and a cessation of the general symptoms of sepsis, amputation should be done forthwith.

As secondary (intra-febrile) resections are performed while suppuration is at its height, some surgeons consider it useful to apply continuous extension to the leg, so as to maintain a cavity for drainage between the two separated bones. This is not a practice to be followed : intense septic absorption occurs from the recent bone sections which are thus bathed in pus ; the cancellous bone inevitably becomes inflamed and infected, and even if the patient recovers from a slow septicæmia, the ultimate consolidation of his limb is gravely jeopardised. It is much better to stake everything and do the operation exactly as has been indicated above for primary resection ; it is reasonable to hope that infection will soon cease, and that the freshly cut bony surfaces, carefully juxtaposed, will not become fresh centres of osteitis. In that event we may proceed as if we were in the presence of a recent wound.

To sum up : when we have to deal with a suppurative arthritis not yet treated, arthrotomy with drainage and resection should be considered. Arthrotomy with extraction of the missile and drainage is suitable for simple synovial injuries ; resection is the method for articular osteitis. If either mode of treatment proves a failure, amputation should be done without delay.

2. *The patient has been operated upon insufficiently or has been badly looked after.*—In this very frequent case the patient arrives at the base with an enormous infiltrated knee, œdematous, painful, and riddled with drainage tubes (I once found eight, measuring together 55 inches in length); he has been operated upon too late, or foreign bodies have been left in the joint. His condition gives the impression that any intervention would be dangerous, that it might give an impetus to the disease by provoking an acute septicæmia, and that then amputation would become necessary.

In short, the decision is always a very delicate one; it should never be made off-hand, except where amputation is obviously urgent. At first the patients should be kept at rest, and, if necessary, means adopted to secure better immobilisation. For five or six days, if one's hand is not forced, one should study the temperature chart, examine radiographs, determine the existence of foreign bodies and define their precise position. Once the necessary information is in hand, various alternatives present themselves.

(*a*) There are many cases where amputation should be done without hesitation; it should be done (by the circular method in the lower third, with a very long skin flap, and no sutures) when the temperature is hectic in type; when the constitutional condition is very depressed and there are albuminuria and œdema of the ankle on the sound side; when, by radiographs, there are seen to be extensive bony injuries (femoral or tibial); when the atrophied thigh shows the dry œdematous skin of chronic œdema which the finger pits (a condition in which phlebitis of the small veins round the joint is to be feared); when there are pockets of pus behind, in the thigh and the leg, which have defied well-planned incisions; and, lastly, when there is secondary hæmorrhage.

These are questions of degree, and no absolute rules

are possible. But speaking generally, in the cases indicated above, there is everything to gain by rapid amputation. It is also necessary to amputate in the case of those who have had a resection done after arthrotomy has failed, and in whom the two successive operations have been done too late.

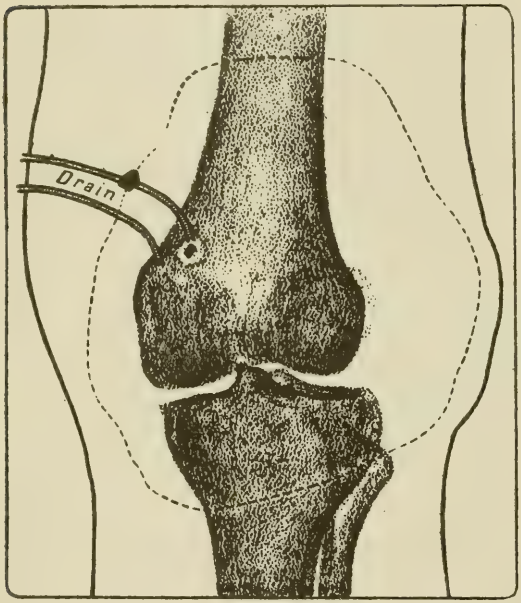



FIG. 75.—Radiograph showing the defects of drainage after arthrotomy. The patient from whom it was taken had been operated upon primarily at the front by double arthrotomy, four large drainage tubes being used. He was evacuated at the end of three weeks with an enormous knee, which was rounded and painful, and a temperature standing at 38·5°.

On arrival, an exploration with Bergonié's "vibreur" revealed the two foreign bodies shown in the radiograph: one was in the track of a drainage tube, the other in contact with the bone at the very spot where the tube impinged. It was sufficient to incise the track and remove the projectiles. A primary operation well performed would have obviated ankylosis.

(*b*) There are cases where resection ought to be tried.

These are the patients whose general condition is still good; who have no serious septicæmia, and in whom the bony injuries are evidently not very extensive.

Resection should be an early operation, even when suppurative arthritis is present, and not a final operation after a failure by arthrotomy.

(*c*) There are cases in which resection may be tried.

These are cases in which a free arthrotomy has not succeeded in reducing the temperature and arresting sepsis. But one should be under no delusion as to the efficacy of resection in these patients. Some very remarkable successes have been reported, but how many more failures have occurred because the operation has been done too late! If in doubt, it is better to decide upon amputation.

(*d*) There are cases where the fractured patella must be removed. Simple ablation is sometimes sufficient to cause the disappearance of the septic phenomena; the parts under the quadriceps must then be plugged wide open and exposed to the air.

(*e*) There are cases where it is sufficient to open up a collection of pus which has passed unnoticed, *i.e.* an abscess of the popliteal space or the leg, or an abscess between the incisions. I have often caused the temperature to fall and have stopped the sepsis by slitting up the tissues between one drainage opening and another; in the track between them there were burrowing abscesses, sloughs, or fragments of clothing.

(*f*) There are cases where it is necessary to remove foreign bodies from a shut-off synovial pocket. This should be done with as little injury as possible.

(*g*) There are cases where an enlarged knee ought to be treated as a tuberculous synovitis, by deep intra-articular cauterisations with the largest available cautery. Like Delore, who, with Kocher, has called attention to this condition, I have seen a large globular knee, with pale granulations and having all the appearances of white swelling, much improved and eventually cured after energetic cauterisation.

(*h*) There are cases where it is sufficient to do away with drainage tubes and pack the drainage incisions with gauze, so long as the temperature is not raised and there is neither missile nor fracture.

This effect upon the progress of wounds caused by

doing away with drainage tubes is recognised in the case of the pleura ; a similar effect is not surprising when another serous membrane is in question. Small residual abscesses may form in the sinus, but it will be easy to open them later on

(*i*) Lastly, there are cases in which one must temporise, with no great hope of final recovery ; such as cases of phlebitis, unless that has been caused by the presence in the popliteal space of a missile, which should then be removed as quickly as possible.

3. *A patient who has had resection done at the front arrives with symptoms of sepsis.*—Here, again, one cannot give any certain indication ; as a general rule, one will begin by observing the effect of rigorous immobilisation for two or three days. If absolute rest in a plaster casing does not stop the septic phenomena, one will look for pockets of pus behind, in the calf, and in the hamstring muscles, or even in the course of the drainage tubes. One will often find in this way a local cause explaining an alarming degree of sepsis, and recovery can be easily obtained.

But when the symptoms of sepsis do not yield, when the constitutional condition is gravely affected, when there is profuse suppuration with considerable separation of the femur and tibia, and especially when there has been secondary hæmorrhage, the limb must be amputated without delay. It is the only means of saving life.

4. *A patient is seen late, with a fistulous ankylosis, or with marked deviation of the knee.*—These vicious ankyloses are not very frequent, but they exist. I have twice seen a very marked genu valgum following an ablation of the external condyle. Many cases will be seen in the future, if the ideas of certain surgeons on the substitution of limited esquillectomy for the typical operation of resection, without regard to orthopædy, prevail at the front. These patients ought to be treated by a classical orthopædic resection. The

operation is easy, in spite of the ankylosis, for the bone is generally soft. One can saw close up to the popliteal space ; there, the section can be completed by fracturing the remaining bone by slowly flexing the knee. The patella is removed sub-periosteally, and the extremities of the bones nailed together. The operation gives excellent results.

## CHAPTER VII

## WOUNDS AND FRACTURES OF THE ANKLE

### I. Anatomical Types and Clinical Course

BULLET wounds of the ankle are not rare in a war of movement, but they are exceptional in trench warfare, in which almost all wounds in the lower part of the body are the result of splinters of grenade or shell.

(a) *Bullet wounds* occur in considerable variety, of which the most frequent is the transverse bullet track with a comminuted fracture of the astragalus, or a simple perforation of the os calcis, the type of fracture differing essentially according to the bone involved. These wounds are not much infected and do not give rise primarily to severe septic symptoms; but they often develop persistent sinuses, whilst deep in the bone a progressive rarefying osteitis develops. This fact deserves notice, for in all other parts of the body

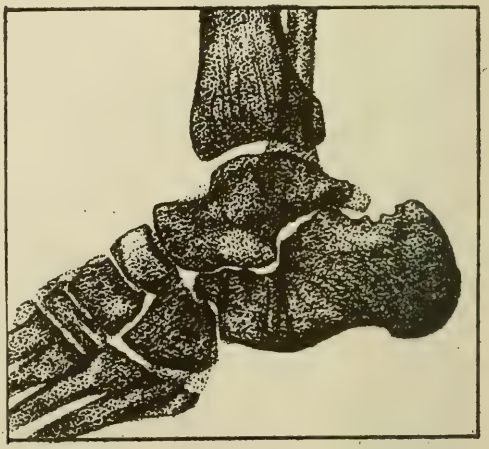


FIG. 76.—Bullet wound in the heel in front of the tendo Achillis. A sinus with slight suppuration.

the wounds caused by long-range bullets usually heal readily and without trouble. I have been able to follow the course of such wounds in two cases. In the case of a soldier, the posterior edge of whose astragalus had been just touched by a bullet, I thought I could safely wait after having simply immobilised the foot and the leg. At the end of three months healing had not occurred, and the parts behind the malleolus remained swollen and painful despite a limited curettage, and so I explored them by means of a suitably wide incision. Through this I removed the astragalus, which was traversed from behind forwards by a Y-shaped fissure, covered with flabby granulations. The os calcis, which was the subject of a rarefying osteitis, was curetted until the compact bone was reached, and after that recovery took place naturally in three months (see figs. 76, 77, and 78). In the case

FIG. 77.—The same patient as fig. 76. Development of a progressive osteitis of the heel, and secondary arthritis of the calcaneo-astragaloid and tibio-tarsal joints.

FIG. 78.—The same patient as figs. 76 and 77. Free intervention at the end of the third month; resection of the astragalus which showed a large fissure from before backwards and had no longer a cartilaginous covering; partial resection of the os calcis. Orthopædic and functional results eventually good.

of a patient who came from the front with the foot simply immobilised in a plaster case for a perforation of the os calcis by a bullet, sustained seventeen days before, I watched in radiographs the progressive extension of a rarefying osteitis which had attacked the joint between the astragalus and os calcis; it became necessary to remove both bones sub-periosteally in order to get healing (see figs. 79 and 80).

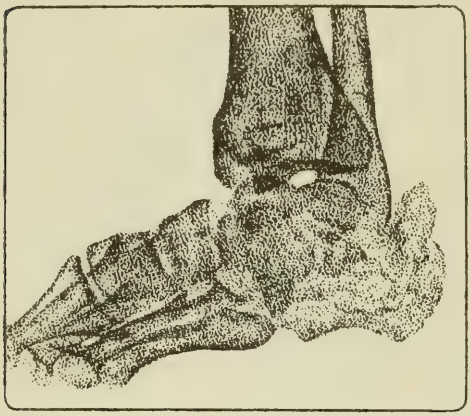


FIG. 79.—Gunshot fracture of the astragalus and os calcis; progressive rarefying osteitis with slight suppuration. Radiograph taken two months after injury. The spread of the osteitis to the anterior tarsus is to be noticed.

(b) *The injuries by splinters of grenade or shell* expose the patient much more to the inroads of sepsis of a more acute character. Sometimes the shell splinter has been driven into the bone, burying itself firmly in the astragalus or the os calcis, without giving rise to any radiating fissures, while sometimes the

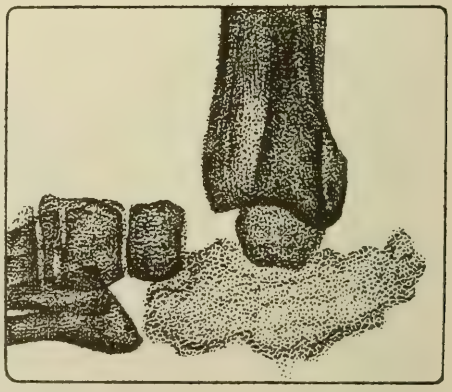


FIG. 80.—The same patient as fig. 79. Total resection of astragalus and os calcis. Recovery in three months. The radiograph reproduced here was taken two months after operation. The periosteal new growth of the os calcis is easily seen.

bone or bones are traversed by them from one end to the other. According to the direction taken by the projectile, there are different types, a knowledge of which is of some practical interest.

*Injury to one bone :*

(*a*) Transverse fracture of the astragalus, with four or five fragments. The most frequent type.

(*b*) Complete or incomplete sagittal fracture with two more or less unequal fragments.

(*c*) A tunnel through the os calcis.

(*d*) Splintering of the posterior part of the os calcis.

*Injury to more than one bone :*

(*a*) Tibio- or fibulo-tarsal combination. Fracture of a malleolus and oblique fracture of the astragalus with transverse fissuring.

(*b*) A combination of fracture of the astragalus and the os calcis sometimes with nondescript medio-tarsal complications (old type ; involving scaphoid-astragalus-os calcis).

As a rule, in these different fractures, radiography gives little help ; a fracture without displacement does not show, and one always finds more than is indicated.

Whatever may be the anatomical type, rapidly progressive septic infection is not immediately manifest, except where laceration of the tendon sheaths exposes them to diffuse phlegmonous inflammation. More often an acute articular osteitis calling for amputation of the leg or a less acute form becoming chronic may develop. The least movement is painful ; there is moderate fever (38·6°C. = 101·5°F.). The general health gradually becomes bad and the patient assumes the characteristic appearance of a man suffering from septic absorption without much suppuration. The aspect is that of toxæmia ; the skin is dry and yellowish-white, the eyes bright, the eyelids rather swollen, the features drawn, the expression anxious ; until, finally, in despair, one performs amputation of the leg.

(c) *Partial destruction of the Foot.*—A moderate-

sized shell-splinter or an explosion of a hand-grenade striking the foot tears away part of the foot, a condition difficult to describe because the appearances are so varied. Through the gaping skin wound are seen torn tendons, vessels twisted and no longer bleeding, or else gaping and giving rise to severe hæmorrhage, joints opened and bones broken or crushed, notably the os calcis, the posterior part of which is often torn away. Unless one intervenes at once, rapid and disastrous sepsis sets in and necessitates amputation on the second or third day.

### II. Primary Therapeutic Indications

In all these wounds, if one waits, infection is a foregone conclusion: it is absolutely necessary to perform a complete clearing operation as rapidly as possible, removing foreign bodies, sloughs, and splinters of bone.

Except in the wounds with punctiform openings, which are very rare, and amenable here as elsewhere to simple immobilisation, intervention is a necessity. What must be done? Three operative methods are possible.

1. **Clearing out the wound combined with Esquillectomy.**—This operation is suitable for:

(*a*) Blind wounds caused by shell-splinters where the missile is fixed in the bone and there are no radiating fissures. In these cases early removal of the foreign body, followed by curetting of the bony cavity, short of a sub-cartilaginous hollowing out of the head and body of the astragalus, suffices to prevent sepsis, and even to arrest it if it has already set in. If the osseous lesion turns out to be more considerable than appears at first, and the curetting happens to reach the cartilaginous covering of the head of the astragalus for example, the cartilage should be clipped away. It is not necessary to undertake a more complex opera-

tion, since simple resection of the head of the astragalus gives satisfactory results (Ollier); the loss of substance is made good by fibrous tissue interspersed with bone particles; the scaphoid is carried backwards, and, except for some diminution in length of its inner side and an increase in the height of the arch, the shape of the foot is not materially altered.

When, on the contrary, the curetting of the astragalus leads to the loss of the whole of the posterior part of the bone, it is better to perform complete excision of the astragalus: unless this is done the tibio-fibular arch loses its support and comes down upon the os calcis, the head of the astragalus is thrust up over the anterior edge of the medio-tarsal joint, the orthopædic result is bad, and the foot is ankylosed and painful. There is thus no economy in doing a resection confined to the body of the astragalus.

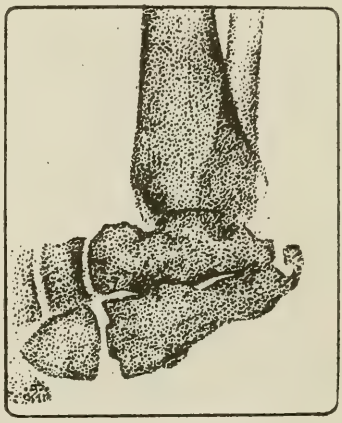


FIG. 81.—Result seven months after a sub-periosteal resection of the os calcis for a complicated fracture due to accident. The operation was done four years ago; the functional result is excellent.

In the case of the os calcis, on the contrary, hollowing out of the bone is the operation of choice, not only in blind wounds with the missile *in situ*, but also in the majority of the complete fractures caused by shell-splinters. I have several times scraped out the whole of the upper part of the bone for severe fractures, preserving only its plantar surface, the great tuberosity, and the insertion of the tendo Achillis. The results have always been perfect from the orthopædic point of view. Complete resection is only rarely indicated, but in a case of total destruc-

tion, there need be no hesitation in employing it; in spite of the many inconveniences of which we shall speak (p. 244), it is a very good operation. I was once able to follow up a patient from whom I had removed the whole of the bone for a comminuted fracture: the periosteum had regenerated a solid calcaneal mass of bone, the work of the foot was well performed, walking was painless, and there was scarcely any lameness. I am at the present moment treating a patient of Gazet's in whom the result is excellent, in spite of great loss of the tibial soft parts.

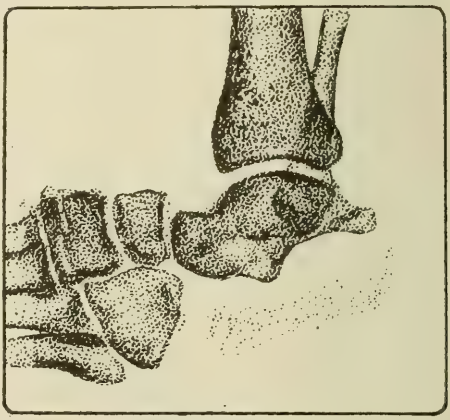


FIG. 82.—Sub-periosteal resection of the os calcis for fracture by shell-splinter. The periosteal regrowth of the calcis is well shown. Four months afterwards cicatrisation was complete: the astragalus was up against the arch; the os calcis is represented by a dense layer of periosteum.

Esquillectomy is also well suited to certain combined injuries of the tibia and astragalus: this will be considered in connection with resection. In short, atypical partial operations are indicated for blind fractures with the missile *in situ*, for injuries localised to the head of the astragalus, and for fractures of the os calcis.

2. **Sub-periosteal Resection.**—In the ankle, resection really means ablation of the astragalus, rather than ablation of the astragalus plus resection of the articular surfaces of the tibia and fibula. In military surgery it is the same thing: one should never do complete tibio-tarsal resection, that is to say, remove the astragalus and the tibio-fibular joint, any more than

one should remove both os calcis and astragalus for calcaneo-astragaloid injuries. As Ollier has clearly established in tuberculous lesions, the cavity made by sub-periosteal resection of the astragalus gives sufficient room to carry out by means of local operations efficient treatment of fractures involving the malleoli, the astragalus, and os calcis.

Ablation of the astragalus is indicated, then:

(*a*) *In Fractures limited to the Astragalus.*—Immediate excision of the astragalus is the method of choice in these cases, whatever be the agent causing the fracture, because it prevents all possibility of osteo-articular infection, and also because it is the best means of treating the fractures themselves. In peace-time the conclusion had been arrived at that immediate excision of the astragalus was the ideal method of treatment for simple fractures, because, if left to themselves, they generally resulted in painful ankylosis. In military surgery there is no reason why it should be otherwise: a fracture of the astragalus is, strictly speaking, intra-articular, and its union is exposed to the same painful disadvantages as is the union of a simple fracture.

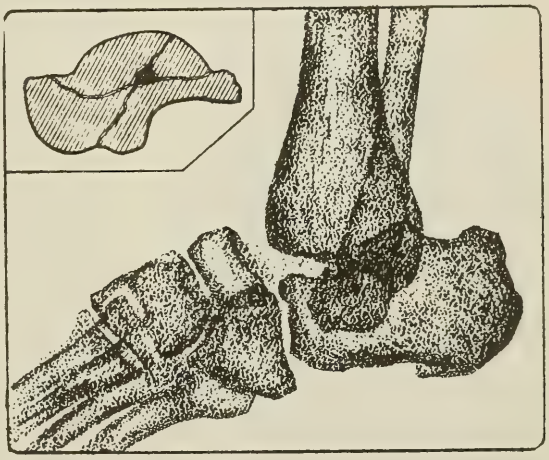


FIG. 83.—Primary resection of the astragalus for fracture by bullet. Aseptic course. Recovery in one and a half months. Very satisfactory result at the end of six months; able to walk with ease and without pain.

I have performed primary excision of the astragalus on four occasions for fracture by bullets, with excellent results.

(*b*) *In Fractures of the Astragalus and Malleoli combined.*—Immediate excision of the astragalus allows one in these cases to deal very sparingly with the malleoli, which is, orthopædically speaking, very important; indeed, one should never lose sight of the fact that it is far preferable to remove the astragalus and preserve the malleoli, than to sacrifice the malleoli in order to preserve the astragalus. The loss of the internal malleolus, if ankylosis of the astragalus to the bones of the leg or the newly formed periosteal bone is not obtained, is accompanied by displacement of the foot upwards and inwards; resection of the external malleolus is followed by rotation of the foot outwards, and walking is very difficult. Excision of the astragalus, on the other hand, gives a very satisfactory functional result.

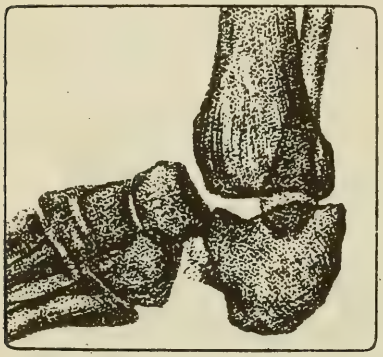


FIG. 84.—Fracture of the astragalus and os calcis by a shell-splinter. Primary resection of the whole of the former and part of the latter; the posterior part of the os calcis with the insertion of the tendo Achillis was left. Orthopædic and functional result after nine months excellent. The patient had at the same time a fracture of the opposite tibia which was treated by primary sub-periosteal esquillectomy and healed without sepsis.

If, then, a missile has broken up one malleolus and has then penetrated the astragalus, this latter bone must be resected, but the treatment of the malleolar injury must be limited to clearing it out, by which means the maximum of bone and periosteum is preserved.

The excellent drainage provided by ablation of the astragalus will prevent or check the inroads of sepsis, and the malleolar fracture should run an uneventful course. The longitudinal splinters fuse together and make a rigid pillar of bone.

(*c*) *In Fractures of the Posterior Tarsus.*—When the bodies of the astragalus and os calcis are involved, when the astragalus is broken into four or five fragments and lies upon an os calcis which has been reduced to a pulp, it is necessary to abstain both from amputation of the leg, which is performed too often in these cases, and from a typical resection of the posterior tarsus.

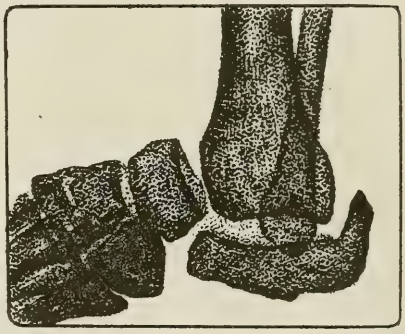


FIG. 85.—Fracture of the astragalus and of the articular surface of the os calcis. Primary resection of the astragalus and curettage of the os calcis. Preservation of the "anse calcanéenne." Orthopædic functional result after eleven months excellent.

By removing the astragalus in the first place, and then exposing the os calcis at the seat of election, enough room is obtained to scrape away completely the cancellous tissue of the os calcis, while preserving all the surrounding healthy parts which will effectually resist infection and give a solid sole capable of maintaining the shape of the foot. The clearing out of the seat of the fractures ought to be done with great attention to detail, so as to avoid the interminable suppuration which follows the retention of fragments which have been overlooked; in practice it will almost always be possible to preserve the posterior lamella of bone into which the tendo Achillis is inserted and the shell of compact bone on its plantar surface. Thus we shall have what Ollier called the "anse calcaneenne," which forms the basis of a firm periosteal

bone formation assuring perfect solidity to the foot, and enabling it to retain its normal shape. The same plan is followed with the great tuberosity, which should always be spared if possible, as it protects the articulation with the cuboid. It is most important to think out these orthopædic details before deciding to intervene in these complicated cases, for typical ablation of the os calcis is a proceeding which makes a great alteration in the support and movements of the foot, whether from the point of view of muscular action or of the movements of the anterior tarsal joints. Ollier said little on this matter. It is true, that before he would admit that the result of an ablation of the os calcis was excellent, he insisted that the patient should be able to walk without appliance and in the normal manner. The same standard should be required to-day. It is for this reason particularly that the plantar surface of the os calcis and the insertion of the tendo Achillis should be preserved. If this can be done, the result will be good in the sense that Ollier used the term, even when the injury has been very extensive. For my own part, I have obtained the best possible results from the method outlined above in cases in which the destruction of the astragalus and os calcis seemed to demand amputation of the foot with a heel flap. The procedure would be the same in injuries that extend to the fore part of the foot, but do not call for total excision of the tarsus. We shall speak of this again farther on.

3. **Amputation.**—This is only indicated if there is an insufficiency of the soft parts, especially on the sole or the heel: the injuries to the tarsal bones, however extensive they may be, ought never to cause the surgeon to amputate, if the condition of the soft parts allows any hope of the movements of the foot being eventually retained. Some means of preserving the foot can always be found, if this condition is fulfilled: excision of the astragalus combined with

esquillectomy of the bones of the leg, or with typical resection of the tibia and fibula, or total excision of the posterior tarsus, especially if performed at once, will avoid the sacrifice of the foot in what are apparently the gravest cases, even if the internal plantar vessels have been severed.

But, on the other hand, if there is not sufficient skin below and on the inner side, if the tendons are lacerated, if the posterior tibial artery and the nerves are cut, amputation low down will be better both as regards the present and the future.

Farther on we shall discuss the method of amputation that should be chosen.

### III. Operative Technique

1. Modes of Access.—A precise knowledge of these is essential from the point of view of the restoration of function. *Exposure of the astragalus* ought to be made by incisions which do not sacrifice any tendon. Whether it be for removal of a foreign body or for ablation of the astragalus, the bones will be approached through the classical incisions, unless there is a special indication for using the wound of entry of the missile; in all cases the latter will always be cleared and explored.

The classical incisions designed to avoid the tendons should be well known: there are two, an external and an internal. The foot being extended on the leg and adducted, the external and more important incision is commenced two inches above the malleolus, at the internal edge of the fibula and outside the peroneus tertius; it runs down to the level of the cuboid in the direction of the commissure of the fourth and fifth toes; perpendicular to it, a short incision about 1½ in. long descends to the tip of the external malleolus. The incision should be free, but not deep enough to divide the tendon of the

peroneus tertius, and especially that of the peroneus brevis below the malleolus. This incision opens the inferior tibio-fibular, the tibio-tarsal and astragalo-scaphoid articulations, and it renders easy the detachment of the anterior ligament between the fibula and the astragalus, and the clearing of the neck of the astragalus and the ligaments uniting the head of that bone to the scaphoid.

FIG. 86.—External incision for resection of the astragalus.

The second incision, antero-internal, passes round the internal malleolus and terminates a little behind its tip. From the centre of this incision, which corresponds to the base of the malleolus, another incision is made downwards and forwards as far as the level of the astragalo-scaphoid joint without going beyond the tibialis anticus tendon; this allows the tibio-tarsal and astragalo-scaphoid joints to be opened. It is unnecessary to make any posterior incisions for drainage. As soon as the incisions have been carried down to the bone, the work of the rugine should commence; it ought to be used with much care, and by its means

FIG. 87.—External elbowed incision for exposure and resection of the os calcis.

the insertions of the ligaments into the periosteum are preserved, and one does not lose one's way among the tendons and muscles. When the bone has thus been removed by means of the rugine, nothing is easier than to explore the walls of the gaping cavity.

*Exposure of the Os Calcis.*—The incision should be free and L-shaped, following the external border of the tendo Achillis and then the outer edge of the sole. The tendons of the peronei are drawn upwards and forwards by retractors, and in this manner enough room is obtained without endangering neighbouring tissues, so that it is easy to do all that is necessary to the os calcis. The principle underlying these operations is to do only atypical operations with the rugine and curette, sparing if possible the "anse calcanéenne," in preference to complete resections.

2. AMPUTATION.—The systematic resort to early resection much reduces the indications for amputation. Should this appear necessary, one of the four following methods should be employed, according to circumstances.

*Sub-astragaloid disarticulation*, which is sometimes possible when much of the plantar skin remains.

*Pirogoff's amputation* through the os calcis, or one of its modifications, whenever the condition of the bone will allow.

*Syme's tibio-tarsal disarticulation*, or that of J. Roux by an internal flap, with decortication of the os calcis by means of the rugine, so as to leave the periosteum on the shell of bone, which will form an osteo-plastic centre, as recommended by Ollier.

*Guyon's supra-malleolar amputation* with a posterior flap.

*Amputation in the lower third of the leg.*—In practice the first two forms of amputations are seldom indicated in injuries of the posterior tarsus; when a Pirogoff or a Syme is possible, excision of the posterior tarsus is generally equally so, and that operation is

always preferable. Still, whenever an amputation with a heel flap is practicable, it ought to be chosen, its functional results being so satisfactory.

If the injuries are very considerable there is no need to keep to one of the set operations and so to amputate high up the leg. Irregular atypical flaps should be cut at the level of the wound, and the bone should be sawn a little higher up than is necessary from the point of view of length of the skin flaps, since the wound must be left open and without sutures.

Sometimes sutures may be inserted after some days, but it is always necessary, in spite of this, to expect considerable retraction of the skin.

### IV. Post-Operative Treatment

1. **After simple Curetting of the bone (Astragalus or Os Calcis).**—It is sufficient to place a gauze wick in contact with the bony cavity, and to immobilise the limb in good position in the simple posterior plaster splint extending above the knee, as described on page 220; this should be removed at each dressing, and must be remade if the plaster becomes soft. If necessary, its place may be taken by an iron wire splint. The first dressing should be left undisturbed for a week at least, if there is no rise of temperature; then the gauze drain is abandoned, and only infrequent dressings are required. Passive movements are commenced towards the tenth day. Walking with the weight borne direct upon the ground will not be allowed for at least a month. Recovery is generally very rapid.

2. **After simple Astragalectomy.**—The joint cavity is lightly filled with aseptic gauze; a strand of that material is introduced through each incision, so that they meet one another. It is wrong to pass a drain of this type through from one side to the other; its removal is much more painful. It is unnecessary to insert drainage tubes. Too much dressing must not

be put on before applying the first bandage, and the dressing will not have been well applied unless the foot remains in good position, without the least tendency to displacement, when the bandage has been applied round the foot and carried up to the middle of the leg.

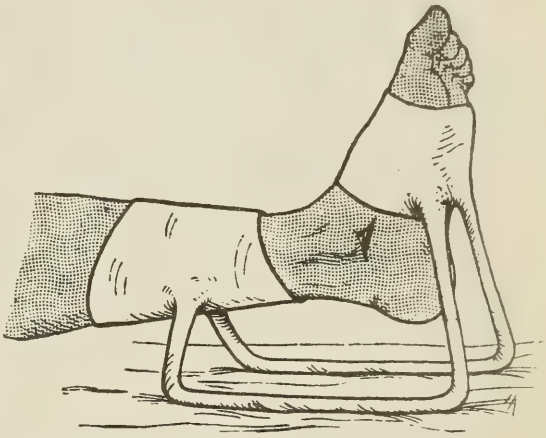


FIG. 88.—Interrupted plaster casing after resection of the astragalus.

Immobilisation will then be effected by the classical posterior plaster splint, as above. One should wait as long as possible before doing the first dressing—ten days if all goes well. If, on the first day, the blood-stained discharge has soiled all the dressings, only the superficial layers need be changed, for it is very important not to disturb the wound, and to give the tissues time and opportunity to organise their defence and commence their repair.

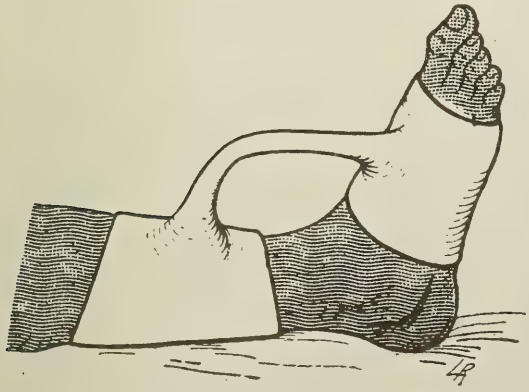


FIG. 89.—Interrupted plaster casing after resection of the os calcis.

Toward the tenth day the gauze drains are removed and replaced by others.

If any abnormal oozing necessitates frequent changes of dressings, an interrupted plaster casing must be provided, but this should not be regarded as the best apparatus since it does not immobilise well, especially at the instep, and it requires more supervision ; in short, it ought only to be used on account of free oozing, or after the ligaments round the joint have recovered their power.

This apparatus is made in the following manner : a circular bandage surrounds the lower half of the leg as far as the malleoli ; a second embraces the front half of the foot as far down as the toes. These two portions are united either by a single bracket of hoop-iron in the long axis of the leg and foot or by two of them applied laterally or else posteriorly, when they act as supports.

When the plaster is dry the heel must be carefully supported by means of a wide bandage after each dressing, and this should be converted into a sort of hammock fastened to the anterior bracket until the front part of the foot becomes fixed by its ligaments.

During the whole of the post-operative treatment constant care is required to keep the foot in correct position. If the foot rests too much on the heel, it is pushed forwards ; if it is not properly supported, it slips backwards ; if the sole is not firmly maintained in its normal position, it tends to be rotated inwards into a position of varus. Unless he is carefully watched, the patient will have a deformed foot, and it will be difficult to correct this deviation when the plaster is left off.

When a tendency to deviation is noticed, a fresh plaster casing should be applied to correct it without delay under chloride of ethyl anæsthesia. This is better than the classical traction upon the foot with an elastic bandage, which patients usually omit to use and which produces little result.

Attention should also be paid to the toes : they

should be frequently moved, to counteract stiffness, as they have a pernicious tendency to assume the shape of a plantar claw.

Walking is not allowed until the end of three months, when a plaster support is employed while waiting for the permanent support (a boot with lateral irons extending to just below the knee). There should never be any hurry in seeking for mobility, which is almost always recovered without trouble; it should only be obtained after the parts have become firm.

The same care will be required after a typical resection of the os calcis, but the post-operative supervision should be more prolonged, and walking should only be permitted after a longer interval (four or five months).

3. **After a complex Resection.**—The line to follow is the same, but immobilisation should be of longer duration. If the malleoli have been involved in the operation, their solidification and regeneration will be a lengthy proceeding. Until the parts have become quite firm the patient must not be allowed to walk. If the parts do not become firm, it is better to try to get bony union between the os calcis and the tibio-fibular arch, if necessary by curetting the cartilage from it. This will take at least four or five months, and it must not be expected that these patients will be able to walk without a stick before eight or ten months.

It is the same in resection of the astragalus and os calcis.

4. **After Amputation.**—The operation is completed without suturing the flaps, but at the end of a few days, when there is no longer fear of infection, stitches may be inserted. One or two can be used to bring the plantar flap into apposition with the anterior surface of the leg, and in this manner the convalescence may be shortened and a better stump obtained.

### V. Evacuation of Patients with Ankle Wounds

These are generally capable of speedy evacuation: a patient operated on by localised curetting of a bone can be put on the rail forty-eight hours afterwards; a resection of the astragalus, at the end of from six to eight days; a complicated resection, at the end of from ten to twelve. In cases of extreme urgency all of them can be evacuated at the end of forty-eight hours much more easily than if they had not been operated upon.

For the journey, the ideal apparatus is the posterior plaster casing, which immobilises well, does not hurt, and allows easy supervision of the toes and the leg.

### VI. Treatment of Patients seen late or after Evacuation

The patient operated upon early by limited esquillectomy for injury of the bone, or by resection for an extensive fracture, heals rapidly and without incident. It is otherwise when the prophylactic operation has been omitted or has been done insufficiently.

1. A Patient is seen after a long interval.—A patient seen after twenty-four hours or still later, not treated at all, or insufficiently, usually shows signs of suppurative arthritis of the ankle with severe constitutional disturbance, an enormously swollen foot with livid patches up the leg, and œdema of the front of the foot and the toes. Examination is impossible as the pain is too acute. *Suppurative arthritis of the ankle* is amenable to immediate surgical measures which will probably take the form of an arthrotomy by the two exploratory incisions described above, to which should be added two counter-openings behind the malleoli for drainage between the bone and the tendo Achillis. The presence of the posterior tibial vessels on the inner side must not be forgotten.

This arthrotomy may suffice, but as we are dealing with a close-fitting joint, in which the bone is

fractured, it is safest for the present, and best for the future, to perform excision of the astragalus at once. This operation gives good drainage, and arrests the sepsis with certainty. Sometimes it has to be completed by incising purulent foci in the tendon sheaths, notably in those of the peronei. These incisions are called for if the temperature remains high after resection and there is any lateral swelling extending up the leg. At times it is necessary to carry the incision far up the leg, and it is not uncommon to see the tendinous and aponeurotic tissues slough later. Should this be the case, in order to accelerate recovery, they should be excised instead of its being left to nature to get rid of them.

It is often possible to avoid amputation, if the necessary steps are taken at once. If the gravity of the general condition or the extent of the lesions (suppuration of the whole of the foot and leg) makes amputation unavoidable, disarticulation of the foot by Syme's method or amputation of the leg should be performed ; it should not be forgotten that a plantar flap can be used, even if the section of the bone has to be carried high up (2 or 2½ inches above the external malleolus).

2. A Patient arrives with Sinuses.—These suppurating sinuses about the ankle call for excision of the astragalus, if this be the bone that is the seat of mischief. Time must not be lost in repeatedly scraping the seat of the osteitis. In a bone as badly vascularised as this and composed of a mass of cancellous tissue, osteitis spreads rapidly and involves the whole bone ; besides, the repair of a cavity scooped out with a curette cannot be effected by the sinking in of its walls. A cure is very difficult unless the entire bone be removed.

If there are sinuses leading to the os calcis, no decision should be made without radiographs ; very often indeed osteitis of this bone reaches the joint

between it and the astragalus, and usually, save when it occurs in the posterior or plantar margins, it becomes necessary, from what I have seen, to begin by removing the astragalus, in order that curettage of the os calcis may have good results. No precise rules can yet be laid down for this, but the ideas here indicated must not be lost sight of.

3. A PATIENT IS SEEN WITH A VICIOUS ANKYLOSIS, complete or otherwise, fistulous or not, the foot being fixed in equinus. If the astragalus is affected, it must not be thought that the tendo Achillis is alone at fault, and that tenotomy will suffice. Vicious ankylosis of the ankle ought to be treated by simple excision of the astragalus, which in these cases gives perfect orthopædic and functional results.

## CHAPTER VIII

# WOUNDS AND FRACTURES OF THE ANTERIOR TARSUS AND THE FORE-PART OF THE FOOT

### I. Anatomical Types and Clinical Course

ALL the wounds of the anterior tarsus are due in practice to splinters of grenade or shell. Two factors dominate their course: the frequency of lesions involving many bones, and accordingly many joints; and the constancy of the speedy incidence of sepsis producing diffuse suppuration of the anterior tarsus, which is too often treated by amputation, when early operations and primary resections would almost always avoid loss of the foot.

The anatomical types are very diverse, and it is difficult to classify them except very theoretically. We may find:

Fracture of one bone only by small splinters of shell, with the missile often remaining in a blind wound.

Oblique punctured fracture of many bones, the wound extending from the dorsum to the sole, and involving either the outer or the inner arch of the tarsus.

Punctured transverse fracture, the wound going from one edge of the foot to the other.

Complex fractures of the tarsus and metatarsus.

Complex fractures, involving the posterior tarsus.

When one bone only is affected, a localised suppurative osteitis may occur, and after the formation of an abscess a sinus may form without the inflammation

spreading to the neighbouring bones, joints, or the soft parts of the sole. But as a general rule, when a single bone is broken, there are fissures which radiate towards the contiguous bones; when several bones are fractured, although the five synovial membranes of the fore-foot may be normally independent, there is almost always a progressive invasion either of the external group, of one of the internal groups, or of the whole of the anterior tarsus. So that, in a number of cases, the anterior tarsus may be considered as one bone, articulating in front with the metatarsus, and behind with the astragalus.

When there are lesions of the metatarsus, the situation is still more complex. In the close-fitting joints between the metatarsal bones infection easily spreads in spite of any drainage, and speedily leads to septic symptoms which it is no easy matter to check, except by the complete removal of the fore-foot, or even of the entire foot.

In the fractures which extend to the posterior tarsus the position is quite as serious; the multiplicity of the folds of synovial membrane make it difficult to act to any useful purpose, while it is impossible to drain such numerous and irregularly situated cavities. The gravity of the local phenomena in all these lesions, and the intensity of the general reaction, soon demand incisions and mutilations, which an early operation would have avoided.

### II. Primary Therapeutic Indications

1. **Esquillectomy, or Resection of a single Bone.**—In practice esquillectomy is almost always ablation of one of the small bones of the anterior tarsus. It is indicated when a single bone is fractured, with or without a missile *in situ*. In this case the extraction of the projectile and the early scooping out of the cavity in which it lies give excellent results.

The scaphoid, or one of the cuneiform bones, can be removed in this way, and early resection of one bone is the best means of preventing the spread of sepsis. In the case of the scaphoid in particular, the operation gives perfect results, and resection of this bone alone ought always to be practised when possible. But, if the lesion is more widespread, if many bones are involved, or many synovial membranes are opened, there must be no hesitation in completely scraping out the bones affected, however atypical the operation may be.

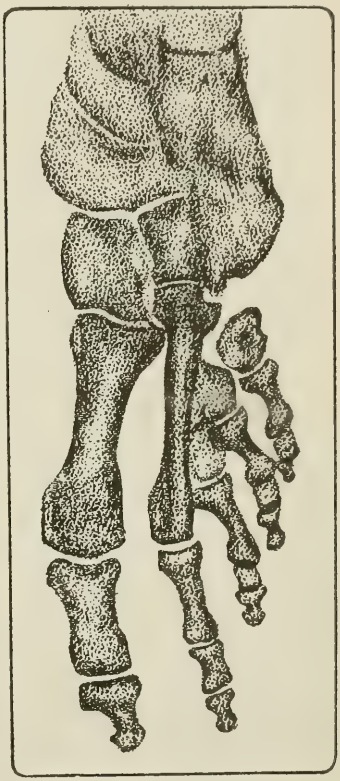


FIG. 90.—Sub-periosteal resection of the cuboid and of the third cuneiform with subtotal resection of the last three metatarsals. Orthopædic result excellent. The officer upon whom this operation was performed has been able to rejoin an Alpine battalion. This radiograph was taken on the occasion of a second wound seven months after the first.

It is important that this should be carried out everywhere in healthy tissues and with free incisions, without which atypical operations become dangerous. There is, however, a limit to this lateral loss of tissue ; when more than a third of the total width of the tarsus becomes involved in these resections, the orthopædic result will be unsatisfactory. The lateral loss of tissue cannot be filled up with firm new growth. The corresponding metatarsal bones are gradually displaced, at first backwards and then inclining laterally; adjacent metatarsal bones

become deflected at the point of their attachment to the tarsus.

This causes secondary varus or vulgus, with painful deformity of the sound side of the foot or of the sole. That is why Ollier decided on orthopædic grounds in favour of total excision of the anterior tarsus, whenever it is impossible to leave intact rather more than one-half of the width of the tarsus.

Good results may nevertheless be got by getting rid of the metatarsals corresponding to the damaged bones, especially if they are injured. The functional result of this excision of tarsus and metatarsus is good, but its appearance is deplorable.

2. **Resection of the Anterior Tarsus.**—When many bones are fractured, especially in the transverse direction, one must consider the necessity of an extensive operation. If the injuries exceed one-third of its width, the tarsus should be treated as if it consisted of a single bone with a wide periosteal covering reinforced by numerous and firm ligaments, and having only two articular surfaces, in front, the cartilaginous surface of Lisfranc's joint (the junction of the tarsus with the metatarsus), and behind, the head of the astragalus. The entire anterior tarsus should then be removed by sub-periosteal resection. If, however, the scaphoid is healthy, it should be left in place, and no more will be done than ablation of the three cuneiforms and the cuboid ; a partial operation which is followed by slight valgus, but which allows the patient to walk excellently and is quite commendable.

These different indications may appear a little theoretical, and certain surgeons think they need not be taken into account. Satisfied with the immediate result, they imagine that the orthopædic result is one in which they have no further interest, since they suppose, from want of experience, that it will be all they desire. The observation of end-results would quickly undeceive them. But it is not necessary to

be eternally repeating the experiences of the past; the end-results of these operations have been clearly ascertained in times of peace, and orthopædic principles are not changed by the nature of the injuries.

When fractures of the tarsus are complicated with radiating fissures extending to the metatarsus, the opportunity arises to combine esquillectomy of the metatarsals with the tarsal operations. If a partial operation is decided upon, the metatarsal bones should not be interfered with more than is strictly necessary. If, on the other hand, resection of the anterior tarsus is deemed advisable, the line of the tarso-metatarsal articulation must be considered as if the metatarsus were a single bone, and a flush line of section made with the saw.

3. **Excision of the Tarsus (Total or Subtotal).**—When there is a fracture of the bones of the anterior tarsus, and the astragalus, or the os calcis, or both of them, are involved, early intervention is more pressing than ever. A smash of the tarsus is indeed perfectly amenable to a conservative operation, but it must be primary, and the surgeon must not wait for the occurrence of diffuse suppuration before acting. There will be no question of absolutely typical operations, but one must be directed by the principles governing a typical resection, and must recognise that in total excision of the tarsus one has a marvellous means of avoiding amputation. In this proceeding, the fractured tarsus is to be considered as formed of one single bone, reinforced by firm ligaments, and as having only two articulations, a tibio-tarsal and a tarso-metatarsal. When this tarsal mass has been removed by the sub-periosteal method, there remains what Ollier calls a "suro-metatarsal" cuff, which unites the bones of the leg with the posterior extremities of the metatarsals. Behind, the insertion of the tendo Achillis strengthens it; below, there are the ligaments between the cuboid and os calcis; at the sides,

the ligaments between the tarsus and the tibia and fibula. This sheath is very resistent, and when, thanks to the periosteum, new osseous plaques are formed in it, it is able to recover sufficient strength to support the weight of the body and to connect the metatarsus closely with the bones of the leg.

There is a further reason for this operation after destruction of the tarsus by gun-shot wounds. In these cases certain healthy tissues can be preserved, such as the posterior and inferior part of the os calcis, and in these circumstances the orthopædic results will be even better. Atypical clearing out of the space between the tibia and the metatarsus ought to be practised whenever the condition of the soft parts allows, and if, while preserving the periosteum and the healthy bone, one is careful to leave no irregular surfaces, with diverticula which it is difficult to drain, many amputations will be avoided.

4. **Amputation.**—Primary amputation is rendered necessary, rather by the extent of the injury to the soft parts, than by the damage to the bone strictly speaking; in excision of the tarsus, typical or atypical, one can always deal with the tarsus, however extensively destroyed. But if the skin is torn and the tendons are hopelessly damaged, this fundamental idea should be our guide: when dealing with the foot, it is necessary before all things to try to obtain a solid and painless support for walking and for standing.

Consequently, when the destruction of the soft parts is too extensive to allow one to hope for a cicatrix capable of bearing pressure, amputation should be performed at once, but amputation of the leg must be avoided if possible. If the fore-foot and the anterior tarsus are crushed, Chopart's disarticulation will not generally be adopted, or indeed any other measure of this kind; the necessary material for the typical flaps will always be wanting. It will be better to limit

oneself to a level section, and to try later to form a permanent flap. The skin is divided at the level of the contused tissues either on the dorsum or the sole of the foot, keeping as much of the tissues of the foot as possible without disarticulating, but proceeding, so to speak, as in esquillectomy. At a later date, sometimes quite soon if sepsis does not supervene, secondary sutures can be put in and a suitable stump formed : in a case of this kind with multiple fractures, I was able subsequently to cover over the scaphoid and the cuboid, whe.. a typical primary operation would certainly have driven me to disarticulation at the tibio-tarsal joint.

Must Chopart's operation be condemned when there is sufficient material ? One always blames that operation for the " tilted " fully extended stump, which makes the patient walk upon the tuberosity of the os calcis, or even on the head of the astragalus ; and Tuffier does not advise the operation, which has often given, he says, stumps that cannot be used. I have had no personal experience of it, never having performed medio-tarsal disarticulation, but I have seen some patients upon whom it had been done by Bérard, who walked very well. In short, when there is enough skin, Chopart's operation is legitimate, but only in very favourable cases. That is as good as saying that the indications for its adoption will be few.

If the lesions of the soft parts are more extensive, the surgeon will disarticulate at the tibio-tarsal joint, with or without section of the os calcis.

Three types of operation are possible :

Syme's disarticulation with sub-periosteal decortication of the os calcis after the method of Ollier.

Pirogoff's tibio-tarsal disarticulation with oblique section of the os calcis.

Guyon's supra-malleolar amputation.

To sum up : curetting, or resection of a single bone, in cases of limited injury ; partial resection, if the

damage does not extend over more than one-third of the width of the fore-foot; anterior tarsectomy, if the lesions are more extensive; atypical total tarsectomy, if the injuries affect the posterior tarsus; amputation through the tarsus or os calcis, or above the malleoli, if the soft parts are gone, and if the foot is destroyed.

### III. Operative Technique

All the operations on the anterior tarsus ought to be done with the rugine, strictly sub-periosteally, without dividing any tendons in the incisions.

1. Esquillectomy, or Resection of a single Bone.—An incision is made over the orifice of entry of the missile, and when the perforated bone is reached, it is cleared out with a curette. If the injury is slight, the procedure will cease when the missile has been removed; but if the clearing-out process leaves any loose cartilaginous fragments, it is better to remove the bone entirely.

Fig. 91. — The different incisions for use in anterior resection of the tarsus.

2. Resection of the Anterior Tarsus.—The regular ablation of the bones of the tarsus is done according to the indications of Ollier, by means of three or four incisions parallel with the long axis of the foot, so as to sacrifice neither tendons, muscles, vessels, nor nerves. One commences on the side of the foot at which the injuries are most extensive, for example the internal edge.

The first incision will be at this level. It will commence a little behind the tubercle of the scaphoid and will extend down just beyond the joint between the

first metatarsal and the internal cuneiform. The periosteo-capsular sheath will be incised along the lower edge of the bones, whatever injury they may have sustained. A point at which the periosteum and the ligaments are sound is chosen as a starting-point for the detachment, and this is done as completely as possible, passing below the tendon of the tibialis posticus, and following along the abductor hallucis.

The second incision is made along the outer edge of the extensor proprius hallucis, in order to avoid the dorsalis pedis artery which is slightly to its outer side. The periosteo-capsular sheath is opened along the outer edge of the internal cuneiform.

The third incision corresponds with the joint between the cuboid and the external cuneiform, and passes between the fourth and fifth extensor tendons.

The fourth incision lies over the outer border of the cuboid. It follows the upper edge of the peroneus brevis tendon.

This is all no doubt very diagrammatic, and often the extent of the lesions will not permit so rigorous a technique. But the spirit rather than the letter should be followed ; the object is not to divide tendons, but still to have enough room to remove the bones easily. No fractured bone should be forcibly torn out ; it is no advantage to sever with the bistoury the ligaments which fix it in place. Ablation should be effected with the sharp rugine and the ligaments should be preserved as far as possible.

When all the bones are removed, the line of the articular surface of the metatarsus is a somewhat irregular one ; likewise, posteriorly, where the head of the astragalus stands out, as does the second metatarsal in the joint (*i.e.* tarso-metatarsal) of Lisfranc. It is unnecessary to make these surfaces flush ; the periosteum, which has been preserved, levels all inequalities and assures juxtaposition of the astragalus and metatarsus.

After the operation all the incisions are left open, and a gauze drain is placed transversely at the level of the anterior astragalo-calcanean joint.

3. TOTAL TARSECTOMY.—This operation, if performed methodically, allows feet to be preserved which have had their bony tissues completely destroyed. The operation sacrifices the bones of the anterior tarsus and the astragalus, which ought always to be completely removed, but it rigidly preserves the inferior surface and the tuberosities of the os calcis. It can easily be done by means of the incisions for excision of the astragalus combined with the dorsal incisions described above for excision of the anterior tarsus. The entire operation should be rigidly sub-periosteal, so as to preserve as much tissue as possible for padding to fill up the immense cavity left by the operation.

4. AMPUTATION.—The discussion of the various types of amputation already given (page 261) furnishes technical indications for the choice of any particular method according to the case under observation. As to actual points of technique, we need give only the following details :

The transverse incision of Syme is excellent, whenever it is possible. If an osteoplastic amputation is done, it is not necessary to follow the classical rules. The exact extent of the bone-section will vary with the dimensions of the flap available. If ample soft parts are at hand, a typical Pirogoff may be done or the cut surface of the os calcis may be trimmed so as to adapt it to the tibio-fibular arch which is not then resected (Quénu), especially if it is essential to gain time.

If it is necessary to remove the os calcis, decortication of that bone should be done with the rugine, according to the practice of Ollier. The advantage of this is that the flap is thicker, better nourished, and better padded, and finally becomes furnished with an

osteo-fibrous core. It is also easier to do, and the end-result is far preferable.

The heel flap, lined with periosteum, can be used even when as much as four inches of the bones of the leg must be sacrificed. The stump left is no doubt irregular and awkward; but it gradually adapts itself, and in the end the functional result is excellent.

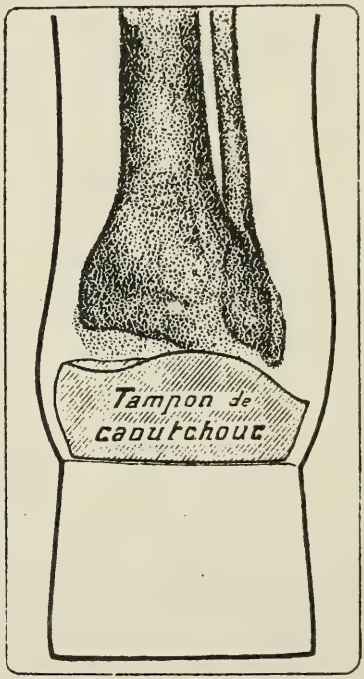



FIG. 92.—Disarticulation of the foot by Syme's operation, without cutting through the malleoli. Walking is easy and painless with an improvised apparatus. The change effected in eight months in the tibio-tarsal articular surface is noticeable

After disarticulation of the foot, it is unnecessary to resect the tibial surface and remove the malleoli. It is customary to do this in operative surgery on the cadaver, but it presents no practical utility. I have seen a patient eight months after a disarticulation in which I had left the malleoli; he walked very well, without pain, and with a boot improvised by himself.

After typical tibio-tarsal disarticulation, it is found advisable as a preventive measure to divide the tendo Achillis. Since primary suture of the anterior and posterior tendons and of the skin flaps cannot and ought not to be done in these cases, the stump would be likely to retract under the pull of the soleus and gastrocnemius. Open section of the tendo Achillis will prevent this; the tenotomy wound can be used

for drainage, and has the advantage that it is at the lowest point.

After the operation, a gauze drain is inserted after the flap has been fastened in place by one or two anterior sutures ; a few other temporary sutures are inserted at the angles. On each side a drain of gauze is slipped into the cavity of the heel, which always oozes. These drains are removed at the first dressing, and if all goes well, the temporary stitches are tied.

### IV. Post-Operative Treatment

This is practically identical with that for operations for injuries of the ankle.

1. AFTER PARTIAL RESECTION OF THE ANTERIOR TARSUS —The foot is rigidly immobilised in a plaster casing which supports the toes and extends above the knee. The dressing must be done at long intervals, so as to secure immobilisation for a very long time, even after cicatrisation ; this is necessary to overcome the traction of the scar-tissue, which tends to cause deviation of the front of the foot. One must bear in mind the frequency of the various deformities which follow this retraction and the dislocation of the foot which may result from the changes which the normal supporting surfaces of the sole have undergone. Later on, if it is not guarded against, there will be a deviation of the bones and projections which will compress the nerves in the sole and cause painful pressure. Before the war late amputations had to be done, because of the painful and troublesome deformity. The process of periosteal repair must therefore be aided by maintaining the foot for a long time in a normal position. Walking will only be allowed some considerable time after cicatrisation has occurred, and then only with an orthopædic boot. It might be worth trying to remedy the defects remaining by the help of grafts of cartilage.

2. After Total Anterior Tarsectomy.—After drainage has been established as has been described above, and the incisions have been plugged with gauze, the foot is immobilised in the usual posterior plaster casing. The first dressing is delayed as long as possible, at least eight to ten days, if there is no rise of temperature. It will then be found that the soft parts have come together to a considerable degree, giving to the foot a peculiar shape so characteristic that it cannot be mistaken for any other condition: the plantar arch has become convex; it is what Ollier has called the "skate-shaped" foot. There is no need to be anxious. This deformity is due to the action of the muscles of the leg, the os calcis being tilted by the tendo Achillis, whilst the anterior segment of the foot tilts in the opposite direction under the action of the extensors of the toes. Little by little the projection decreases, as cicatrisation takes place, and the final result is good. Walking ought not to be permitted before three or four months.

3. After Tarsectomy, Total or Complex.—The foot is immobilised, as usual, in the posterior plaster casing extending up above the knee. This is removed at each dressing, an assistant holding the forefoot with one hand, and the leg with the other. After some time the first plaster casing will have become too large, and a properly fitting one is substituted.

The course of the case is generally uneventful, and complete recovery requires from five to six months. Walking with the weight borne direct upon the sole is not allowed before that time.

4. After Amputation or Disarticulation of the Foot.—No special care is necessary, except after Syme's operation; in the latter, if the temperature is raised, or there are symptoms of local infection, retention of the discharges in the hollow of the heel may be suspected. The best way of checking it is to remove the stitches and let the flap hang widely open.

Afterwards it will be supported and held in place by bandages, which generally suffice to secure satisfactory healing with the flap in the right position.

### V. Evacuation of Patients with Anterior Tarsal Wounds

These patients can be sent away shortly after the primary operation has been performed. After resection of one bone, or after extraction of a missile, a patient can be evacuated at the end of forty-eight hours. An anterior tarsectomy ought to be kept for from six to eight days, a total tarsectomy from twelve to fifteen days. In case of necessity, all of these could be evacuated early, much more easily than if they had not been operated upon.

The journey should not exceed twenty-four hours by rail.

The ideal apparatus for travel is the posterior plaster casing.

### VI. Treatment of Patients seen late or after Evacuation

1. A PATIENT IS SEEN WITH ACTIVE SEPSIS.—If he has been insufficiently operated upon, or not incised, three different conditions may be present :

(*a*) *If it is a blind wound*, caused by a shell-splinter which has not been removed and has caused great damage, there is limited sepsis of the foot with more or less extensive pockets of pus. The necessary incisions will be made, so as to check the acute symptoms and remove the missile, the decision as to which is the best operation for the bone and joint, whether ablation of the bone, scraping out, or typical resection, being reserved for a later date ; this will be made according to the indications from the orthopædic point of view, which are explained above.

(*b*) *If it is a wound penetrating the bone*, the skin

wounds being ragged but not extensive, the case is one of suppurative osteo-arthritis, which is manifested by severe constitutional disturbance, high temperature, and a serious local condition. The whole of the dorsum of the foot as far as the tibio-tarsal joint is swollen and œdematous, with livid patches. From the orifices of entry and exit exudes a turbid discharge. Sometimes the lesion is indolent, and arthritis develops without

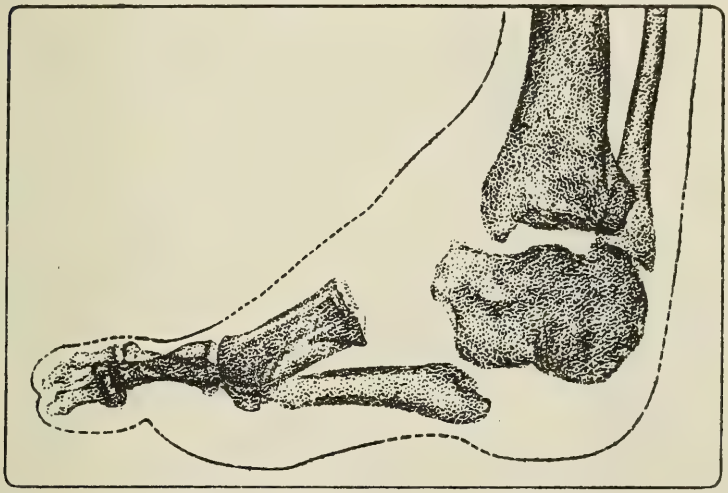


FIG. 93.—Sub-total resection of the tarsus for suppurative arthritis of all the joints. The patient had undergone amputation of an arm at the front for fracture ; he had many wounds : one wound through the tarsus was not attended to on arrival at my station. The patient, jaundiced, weak, and feverish, was in a bad way. A month after resection of the tarsus, which was performed thirty days after the injury, the general condition was much improved and the foot on the way to cicatrisation. Radiograph taken eight days after operation.

much reaction, but the condition is quite as severe. Still, there is no reason to consider that amputation is inevitable.

After radiography, resection should be at once resorted to ; it should be either total anterior tarsectomy, or a complex tarsectomy, sacrificing as much bone as is necessary to obtain a cavity with walls which

are smooth, clean, and free from diverticula. This will often lead to removal of the astragalus as well as the whole of the anterior tarsus, or even most of the os calcis. Any cavity and all pockets of pus must be opened freely. In one case of this kind I only left the os calcis and four of the metatarsals, and even three of these were sawn through just beyond their bases. It might perhaps be objected that disarticulation of the foot would have been better, but such is not the case: the immediate and future results of these operations are excellent, when the operation has been correctly performed, and when the post-operative treatment is suitably attended to.

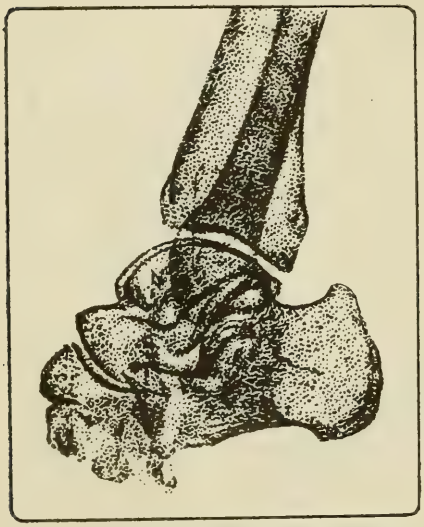


FIG. 94.—Amputation straight through the tarsus. Secondary skin sutures. Walking with a suitable boot is easy.

If the foot is no more than a bag of pus, if the tendons are extensively torn, and if the constitutional condition is serious, without question the decision will be in favour of amputation. When the injury involves the tarsus and metatarsus, amputation will be done by a level section, according to Quénu's advice, through the middle of the tarsus, at the level of the seat of injury, without troubling about the lines of the joints unless the extent of the plantar skin allows of a typical disarticulation. In any case the wound will be dressed wide open and the plastic covering-in will only be done later.

When, on the contrary, a wound of the anterior tarsus is in question, the best operation is disarticulation of the foot, with section of the os calcis, or the Syme-Ollier operation.

If the posterior tarsus is affected, the foot should be disarticulated, or a supra-malleolar amputation done with a heel flap, or Guyon's posterior flap.

The wound is left largely open; the flaps will only be kept together by one or two sutures for the time being.

If the wound is on the surface, and if there has been much laceration of the skin, with loss of muscles and tendons and absence of the soft parts, the septic condition is less grave, but the decision as to the operation most suitable is perhaps still more difficult. When a certain amount of skin has been lost, resection is still possible; in other cases, amputation becomes necessary. It is impossible to lay down fixed rules; it is a question of degree, and a matter for surgical experience. As a general rule, it is best not to sacrifice anything at first.

2. A PATIENT IS SEEN WITH SINUSES.—Unless the injury is very limited, as demonstrated by radiography, a minor operation is not much use; resection is often necessary, and it will be better to do it early, according to the severity of the lesions. In certain cases, disarticulation at the tibio-tarsal joint or amputation through the os calcis is called for.

3. A PATIENT IS SEEN WITH A DEFORMITY OF THE FOOT WHICH PREVENTS HIM FROM WALKING.—A typical resection may be tried, in default of which, the only resort will be amputation (Syme's or Pirogoff's).

# CHAPTER IX

## MULTIPLE JOINT WOUNDS

One frequently observes multiple articular wounds caused either by machine-gun wounds or by shell splinters. Every possible combination is seen, of which the most frequent appear to be wounds of the shoulder and elbow of the same arm, and those of both knees. When this is the case, the customary rule of systematic operative prophylaxis should be more absolute and imperative than ever; any wound near a joint, however small it may be, should not be neglected, even if some other serious accompanying wound appears to demand exclusive attention. This is the only way to avoid cruel disappointments.

An exploratory incision should be made for each joint injured, and the operation se-

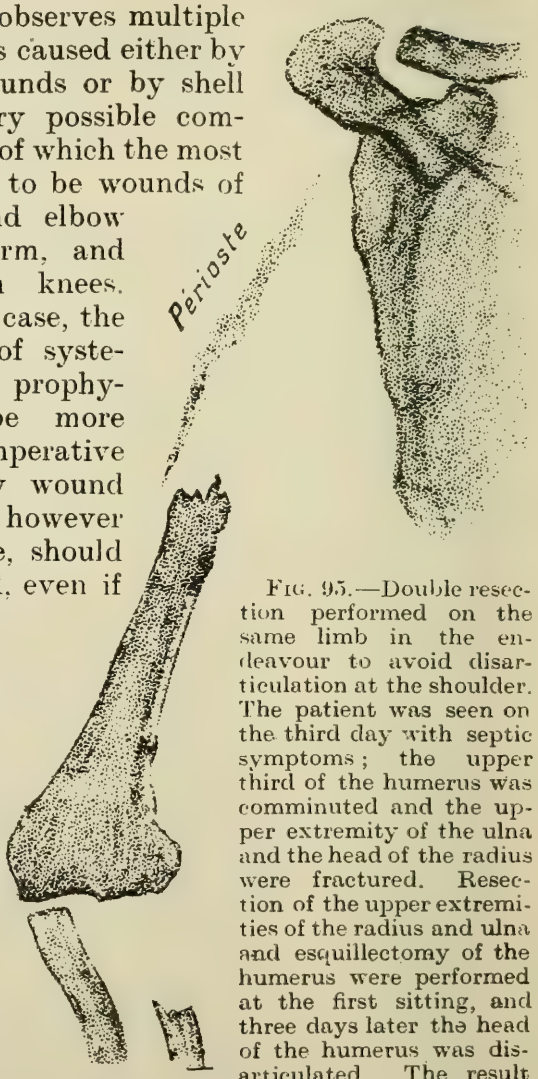



Fig. 95.—Double resection performed on the same limb in the endeavour to avoid disarticulation at the shoulder. The patient was seen on the third day with septic symptoms; the upper third of the humerus was comminuted and the upper extremity of the ulna and the head of the radius were fractured. Resection of the upper extremities of the radius and ulna and esquillectomy of the humerus were performed at the first sitting, and three days later the head of the humerus was disarticulated. The result at the end of six months was as indicated in figs. 96 and 97.

lected will be that which is demanded by what is found: exploratory arthrotomy with simple extraction of the missile if there is no fracture, or with limited sub-periosteal esquillectomy if a slight parietal fracture is encountered; resection in any other case. In short, each articular lesion will be treated as if it existed alone.

In cases of doubt the most radical means should be

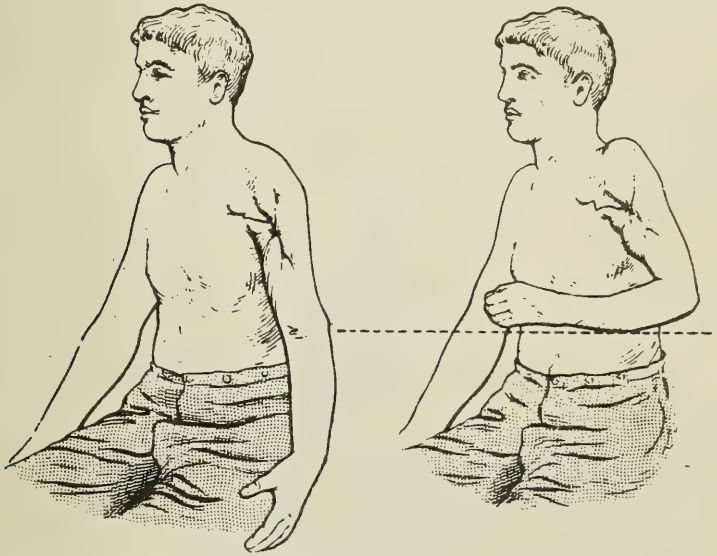


FIG. 96.—Notwithstanding the amount of the humerus which was removed, movements of the arm and forearm were possible to the extent shown in the above photographs. The play of the hand is complete, except for a slight loss of power in the ulna muscles due to a wound of the forearm; the play of the fingers is normal.

chosen. For example, resection should be done in preference to esquillectomy, or amputation in preference to resection, if either of the latter appears at all hazardous.

Sometimes in this way one will be led to do two resections upon the same limb; Gayet has reported a case of resection of the knee and of the astragalus

of the same side. I myself have done, on the same limb, a very extensive double resection of the shoulder and a resection limited to the extremities of the forearm at the elbow, with an excellent result. The wounded man, who has lost more than one-third of the humerus, easily contracts his shoulder muscles in order to draw up the remainder of his humerus,

FIG. 97.—Drapier's apparatus taking the place of the humerus which has been removed and permitting very satisfactory movements of the upper limb.

and to give a solid fulcrum to the flexors of his forearm. This done, he is able, without any appliance, to bring his forearm, with some energy, to more than a right angle. With an apparatus, the function of the limb is very satisfactory, and the hand very useful. Double resection has certainly avoided amputation in this case, which was operated upon when sepsis was in full

swing and the general and local phenomena were grave. It may be added that he had several other wounds of the skull and the face.

In another patient I did an arthrotomy for extraction at the knee and a resection of the shoulder and another of the elbow, with good functional results.

It is seen, then, that even with very extensive multiple injuries, conservative surgery has its indications and its efficacy, but it is of importance to act more rapidly than ever, and to use complete operative prophylaxis against infection for even the slightest wound.

To sum up: in the most complex cases, it is at once necessary and sufficient to apply this fundamental precept of military surgery, which is at the same time the cardinal principle of conservative surgery as applied to joints.

# THE
# TREATMENT OF FRACTURES

## PART. II

## FRACTURES OF THE SHAFT

### CHAPTER X

### A GENERAL STUDY OF SHAFT FRACTURES

APART from the formidable crushing of limbs, with complete shattering of bone and extensive destruction of muscles, blood-vessels, and nerves, such injuries, in fact, as can scarcely be studied as fractures, there are in war surgery, *from the point of view of treatment*, only two great types of shaft fracture: *those produced by long-range bullets*, which strike the limb in the ordinary way, point first, perforating the soft parts and only producing very small wounds as they pierce the skin, and *those caused by other projectiles, short-range bullets, or the explosion of shells, bombs, mines and torpedoes, etc.*

*The former* progress like simple fractures, do not suppurate, and are not liable to serious infection: they get well easily and quickly. These were once regarded as the ordinary type of war-fracture.

*The latter* are always infected at the outset, and the development of the infection, though always a

matter for concern, varies in the severity of its results.*

*The former* are becoming more and more rare in modern warfare even during fighting in the open. No operation, or at least no early operation, should be performed; absolute immobility and continuous extension suffice for recovery. This type will receive little discussion in this book, which concerns itself principally with surgery at the front.

*The latter* form an enormous proportion of our cases nowadays; the operation of sub-periosteal esquillectomy † should be performed systematically as early as possible; in this way all complications that threaten will be avoided, and further progress will be aseptic and end in good union and healing.

It is with this type that I am henceforth concerned.

I must first, however, enumerate the points which distinguish the two types. As a matter of fact, only the nature of the wound of entry need be noted; there is no other means of forming a conclusion, and this one is satisfactory in itself. The skin wounds are very small and insignificant, suggesting, at the points both of entry and of exit, the appearance of a trochar puncture: they are "punctiform" wounds, to use the convenient term which Ferraton has brought into general use. The wound of exit is scarcely larger than the wound of entry: if it is larger than a cherry stone there is some danger of a slight infection, certainly not always, but frequently to a sufficient degree to prevent closure for some time; if it should be as

* Wounds by shrapnel bullets are decidedly less serious than those caused by shell-fragments. They are, in a sense, intermediate between the two groups described above. But though their suppuration is sometimes benign, it can be and frequently is very serious; they should therefore undoubtedly be studied in the category of fractures by shell explosion.

† This term will be used throughout, as in Part I, to denote the removal of bony fragments and splinters after separation from their periosteal covering.—Ed.

large as a shilling, infection is, if not invariable, at least usual.

These "punctiform" wounds must have been caused by bullets only; the insignificant little wound sometimes produced by a shell- or bomb-fragment is as serious as a large wound, if not more so, for, although it appears a small matter from the exterior, there are extensive injuries within.

What is to decide whether we are dealing with a bullet wound or not? The patient's own statement is not enough, as he may easily be mistaken, but a careful examination will usually reveal the truth.

A bullet fired at long range and entering nose first leaves behind it no such track of bruised tissues as is caused by a shell-fragment; the skin wound is clean and not gaping. Anyone who has seen a few fresh wounds will never be mistaken. A bullet, too, which, though it may have travelled some distance, enters with sufficient force to penetrate bone, rarely remains embedded, it almost always passes out; whereas a small shell-fragment usually remains in the wound; besides which, a wound of the latter type is rarely single, there being almost always others somewhere in the region of the small wound corresponding to the seat of the fracture. These distinguishing characteristics, slight as they may seem at first, are perfectly clear, and rarely cause hesitation.

Having said this, I shall now only speak of fractures caused by shell-fragments or short-range bullets.

In spite of the infinite variety of metallic fragments of all kinds, these different fractures correspond very closely in their features, and scarcely need be distinguished.

I shall therefore study them together, treating first, from a general point of view, of *the immediate pathological anatomy of the seat of the fracture*, then of *the course of events in the injured area*.

As the course of events is controlled by *infection*, it

will be well to investigate the circumstances contributing to infection, and the anatomical results of its presence. A knowledge of what is to be feared will show clearly what is to be avoided.

## I. Pathological Anatomy of the seat of a Fracture in its earliest stage

Every projectile striking the shaft of a bone does not of necessity fracture it : *there is no fracture unless the continuity of the shaft is broken*.

Injuries by missiles which do not cause solution of

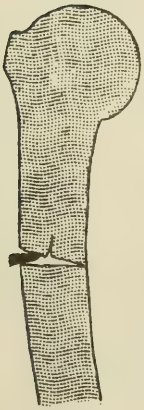


FIG. 1.—Transverse fracture.

FIG. 2.—The large-splinter type of fracture.

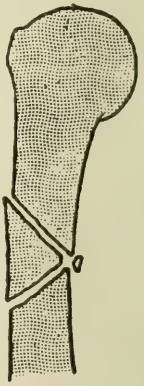


FIG. 3.—Fracture with a large short fragment.

continuity in the long axis of the bone are merely *wounds* of the bone, whatever their form or appearance, whether pitting, furrow, or tunnelling.

Fractures rightly so-called exist in infinite variety, and may be roughly grouped into several types : these main groups can easily be distinguished after examining a large number of X-ray photographs.

The four most important are :

1. *The transverse type* (*unusual*).—This fracture has only one direction, resembling the result of deliberate section of the bone. It may be slightly oblique, but is more often exactly transverse. This fracture is usually produced by the impact of a large shell-fragment, almost spent, which enters the bone like a wedge.

2. *The large-splinter type* (*common*). — There is considerable splintering of the bone in the direction of its length, with one or two large diamond-shaped fragments, the centre of which is roughly the point of origin of the fracture. In other words, the two ends of the shaft taper to points which are in contact, the splinters formed being lodged in the angle which they enclose. Each splinter, about 4 to 6 inches in length, is sometimes split across its centre. There is usually little displacement.

This tapering of the two ends of the shaft is rarely seen except in the femur and humerus.

3. *The type with a large short fragment* (*common*).— In this type, usual in the ulna and tibia, a short and broad wedge-shaped fragment is detached from the shaft and remains in place between the two obliquely pointed extremities of the shaft. The appearance of the whole thing is that of a horizontal V. Sometimes two or three small pieces are found, like little beads, on the side opposite to the main fragment. There are very often fissures extending along the shaft in each direction.

4. *The type with many small fragments* (*common*).— In this fracture the shaft is shattered into a large number (12, 15, or more) of small pieces, more or less obviously radiating from the point of impact. Some, from the middle of the seat of fracture, are entirely free, forced away some distance from the bone, often embedded in muscles, thereby contributing to their laceration, and of no regular shape. Above and below, in contact with the ends of the shaft fragments

remain adherent to the periosteum or muscles, and these, though fewer in number, are usually rather larger than the others. The general impression given is that a mass of small fragments has been impelled in the direction of the exit wound, or at least pushed by the missile in front of itself. There is generally small débris embedded in the surrounding muscles.

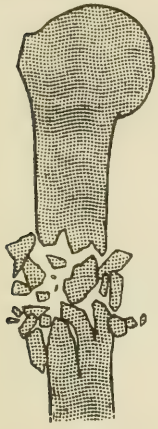


FIG. 4.—Fracture with many small fragments.

One of these types will be recognised in any fracture examined by X-rays or by operation.

Others might be described, notably spiral fractures occurring at the lower end of the tibia, or the V-shaped fractures sometimes seen in the lower third of the humerus, femur, and tibia. All, however, can be relegated more or less rightly to the above categories, or else can be regarded merely as exceptions.

To go into more detail: the fractured area first comprises the following elements:

1. **The Fragments.**—These occur in all sizes and shapes, from mere bone dust to large diamond-shaped fragments 6 inches long.

The smaller they are, the freer they are found to be from all attachment to periosteum or muscle, and the further they are found from the line of the shaft. In general, small fragments are projected distally towards the point of exit, or more exactly, in the same direction as the track of the missile, intra-osseous and otherwise.

This has a practical result of great importance: the first fragments which the projectile pushes forward in traversing the bone end by embedding themselves in the marrow of the shaft at some distance from the point of impact, above all in the spongy tissue of the

epiphyses, thus evading discovery unless their actual position is known. Virtually foreign bodies, they remain in the middle of the injured marrow. Other pieces lacerate muscles and remain embedded there.

Given sufficient impetus, they may happen to lacerate vascular sheaths, and come to rest in contact with arteries and veins, whose elasticity deadens the blow; hence they are very rarely perforated by the original injury. Nerves, being more resistant, are more readily torn or severed. It is not unusual, for instance, to find minute pieces of bone in the sciatic nerve.

When the force of the blow is not so great, the fragments are larger; they remain more or less attached to the periosteum and surrounding muscles. They are lodged in the periphery of the injured area, more or less scattered, sometimes directed towards the point of exit. The larger they are, the more they resist the injuring force whose tendency is to displace them, without actually freeing them altogether from their ligamentous and periosteal attachments. The most adherent are those which an intact periosteum retains in perfect continuity with the rest of the shaft, narrow fissures alone dividing them from it. There are, in fact, all degrees between a free fragment, entirely detached, and the most adherent one; if only two extreme forms are distinguished, no clear understanding of the anatomical details in the fractured area is likely to be reached; this arbitrary distinction has accounted for regrettable mistakes in treatment, and still produces unfortunate confusion in surgical discussion.

Small scraps of clothing often remain caught on the sharp points of long splinters—not the main piece of material which the projectile has carried before it through the bone, but shreds torn away as it passes. They are sometimes embedded and scarcely movable in the crevice between two very adherent fragments, and it is exceedingly difficult to detach them,

The points of splinters, too, and likewise the ends of the shaft, are bruised, crushed, and inflamed, affected by what is sometimes called traumatic osteitis; in fact, they are more or less devitalised by the force of the impact.

In the crevices separating the splinters there is almost always a thin trail of blood-clots, and often, in contact with them, metallic particles which had accompanied the main shell-fragment.

A little cancellous tissue, stained purplish or black with effused blood, is seen on the internal aspect of almost all the splinters.

2. **Fissures.**—There are usually fissures travelling away from the injured area, caused by the spreading of the projectile s energy on impact. In different ways, according to the intensity of this energy, and the particular bone or region, these fissures, instead of meeting and thus forming separate splinters, often run parallel for a variable distance along the shaft towards the epiphyses. If they are very marked, X-rays will reveal them, but more often they are only discovered by careful direct examination; some even appear only on transverse section of the bone.

In fractures occurring close to joints these fissures are very common; their existence explains the appearance of joint symptoms at some distance from the fracture, and accounts for certain complications to which I shall refer later.

In an aseptic wound fissures are of no consequence, and union soon occurs, nothing of them being visible after a few days. But if there is the slightest trace of infection in the main wound, this spreads along the clefts, and gradually reaches the joint cavity, particularly in the case of a fracture below the epiphysis of the humerus or femur.

Apart from such fissures, a second fracture of the shaft is occasionally found at some distance from the other and in a healthy area, generally serrated so that

the ends fit with comparative accuracy. I have seen this in the humerus and femur.

3. **The Medulla.**—At the level of the track of the missile, the delicate marrow seems, as it were, to have evaporated; no trace of it is found except a few masses of blood-stained pulp on the inner side of some splinters. But above, along the large fragments whose arrangement indicates the position of the medullary cavity, it is found to be torn up and bruised for a great distance. Small extravasations of blood are seen high up in the interior of the shaft, at points which would at first appear not to have been affected by the injury. These widespread contusions are produced in the same way as the radiating fissures mentioned above, and have the same untoward results.

The scattering of small splinters into the medullary cavity further increases the extent of the injured area, shattering the network of cancellous tissue and leaving splinters buried in it.

FIG. 5.—Example of fracture with long fissures.

4. **The Periosteum.**—This is sometimes destroyed where the projectile has reduced the bone to fine splinters and scattered them widely. These lose their periosteum, but it is a mistake to suppose that nothing remains of this membrane which previously united them. The periosteum remains for the most part in irregular fragments which at first appear to maintain no independent existence. Further up the bone they are found to be raised in places by blood-clots detached

by an extensive effusion of blood, or displaced by muscular action, partially isolated, in fact, from fragments that have remained in position. Further on, the periosteum is still adherent to the fragments of bone, isolated and apparently mobile though they may be; more or less lacerated in the region of the fissures, it is much more often intact farther from the seat of injury than it is believed to be. It is always delicate, appearing to be a part of the bone; many surgeons suppose that it cannot be separated from the latter, and that without infection to thicken it, the periosteum is surgically non-existent. This conclusion saves them the trouble of looking for it. But for the careful operator, using the sharp rugine, the periosteum always exists, and can always be isolated. Like all fibrous tissues, it is very resistant, and, in the main, it suffers less than any other part of the bone from the passage of the missile. This is well demonstrated during the operation for sub-periosteal esquillectomy; when, approaching the fracture from the exit wound, free splinters, shreds of muscle, and clots have been removed, and as soon as one or two splinters have been detached that had been maintained in position by the periosteum, it is clearly seen that

FIG. 6.—Double fracture of the humerus, one direct caused by a shell-fragment and a jagged indirect fracture below it. Early sub-periosteal esquillectomy of the fractured area has permitted clinically aseptic development. Continuous extension and abduction applied below the fractures has reduced the latter, and union has taken place with a shortening of about 1 inch.

the osseous space is everywhere defined by a fibrous and opalescent sheath. This sheath usually retains its continuity at some point in its circumference; the injury to it is less considerable at the point of entry than at that of exit, and it forms a kind of mould of the missing portion of bone. Unless great care is taken, or if those splinters are sharply pulled or twisted which seem only weakly adherent, but are often more tenacious than is supposed, nothing of this is seen. Fibrous fragments float freely about on the confines of the fracture, becoming mixed up in shreds of muscle, and it may be said that the periosteum no longer exists. This may be so, but the blame for it lies with the operator.

FIG. 7.—Diagram of a fractured area.

Only in cases of fracture by a short-range bullet, with powerful explosive effects, is there in some parts total destruction of the periosteum, and even here, large flaps of it are found, which when brought together form a kind of sheath with little interruption.

In brief, the region of the fracture, bounded by injured muscles, roughly assumes the shape of an irregular spindle. In the centre is a mass of clots, muscular débris, and small pieces of bone, arranged about its transverse diameter; at one extremity are free splinters scattered in the soft parts, and converging from the medullary cavity to a point marked by the exit wound. The entire picture is that of a cone, its base turned towards the bone, and bordered above and below by isolated osseous fragments. The fragments still adherent to the periosteum, and connected by it with the shaft, point towards the exterior and

form the axes of the spindle. Above and below, their periosteum encloses the most distant fissures and connects the fragments with the uninjured shaft, somewhat after the manner of a calyx.

At the extremities of its vertical diameter contusions are still found, little as injury might be expected there. Fissures are found in the dense tissue of the shaft, and the bone-marrow is dark with effused blood.

When once the space between the bones is cleared, the periosteum remains like a mould in two vertical pieces, completely encircling the injured area. But it must not be supposed from this that the splinters form a regular bony cylinder whose removal will at once produce a corresponding shortening of the limb. More often, except perhaps in fractures produced by bullets fired at point-blank range, only certain portions of the shaft are splintered. The two pointed extremities of the shaft meet at their apex, and to some extent ensure the continuity of the bone without loss of intervening osseous material, even after removal of all the splinters.

5. **Injuries to the Soft Parts.**—Laceration of these varies a great deal according to the conditions of the wound: a small wound of entry and a large one of exit with hernia of muscle in wounds by short-range bullets, a single insignificant wound from certain fragments of bomb or shell, the cutaneous wound being usually much smaller than the missile causing it, and a large irregular and ragged wound caused by a number of separate shell-fragments.

The wounds are naturally not always opposite the point of fracture. With different angles of incidence, all directions are possible for the track of the missile; when all the possible different positions in which the limb may be when the wound is inflicted are considered, many curious results are observed.

The cutaneous wounds are generally bounded by a zone of crushed and bruised tissue, often impregnated

with soil and shreds of clothing. Very shortly the edges become distinctly ragged. Below this, the fasciæ are torn, often very widely, but as a rule, particularly in certain regions such as the thigh, the upper two-thirds of the leg, and the posterior aspect of the arm and forearm, the entry wound in the fascia is small and its edges are rigid and stretched, gripping a small hernia of muscle which seems to be trying to fill up the track of the missile.

When the injury to the fascia is extensive, the muscles lie immediately beneath the skin; they are more or less lacerated, and rapidly assume the appearance of gangrenous tissue, and often have an unpleasant friable granular feeling to the touch. Small thrombosed veins and blood-clots are found beneath the skin and along the muscles. The more or less gangrenous muscle constitutes a curtain hiding the end of the track where the fracture is situated. In the exit wound the injury is more extensive, and fragments of bone, scattered by the violence of the impact, augment the damage caused by the missile itself.

Muscular involvement extends some distance from the region of the track; sheaths are infiltrated with blood and loosened; fibres severed by the missile retract towards their insertions, extending the effects of the injury for a considerable distance. These are the chief features: widespread muscular injuries, interstitial hæmorrhage here and there and slight evidences of explosive effects, encountered sometimes at points that seem astonishingly remote, even to one accustomed to finding them.

Blood-vessels and nerves are usually uninjured.

*Primary injuries of vessels* are in the main unusual, except in the arteries of the forearm. Laceration sometimes occurs in the femoral artery in fractures of the upper end of the femur, in the brachial in the upper part of the arm, and in the posterior tibial high up in the leg. Hæmorrhage, however, is not often extensive,

and many injured vessels do not even bleed at all, and the lesion escapes notice at first unless they are disturbed. There are no doubt many which do bleed, but such cases die before reaching an ambulance. Though actual wounds of vessels are unusual, arterial contusions are far from being so. In aseptic wounds they heal without giving rise to any particular symptoms, but if there is any infection, a diseased patch develops, and subsequent ulceration may lead to fatal secondary hæmorrhage.

*Nerve lesions* are more common. Taking all war-wounds together, however, this complication is an unusual one. It is difficult to state an exact proportion, since a good deal of traumatic paralysis may escape recognition during a large influx of cases. I have counted barely 8 per cent., but this figure is valueless. There are some fractures which never involve nervous lesions, and others in which they are a common feature; that of the upper third of the humerus, for instance, causes, in my experience, radial (musculo-spiral) paralysis in 16 to 18 per cent. of cases. Ulnar paralysis often complicates fracture of the ulna, and sciatic paralysis sub-trochanteric fracture of the femur. The injury to the nerve is almost always caused by the missile and not by splinters.

6. **Displacement and Over-riding.**—There is usually little displacement in these fractures, relatively at least to the amount commonly seen in civil practice, although the fracture extremities do not fit, and there is always damage to the periosteum; in some fractures there is no initial displacement whatever, since the partial destruction of muscles and tendinous insertions prevents the exertion of any pull on the fragments of the shaft. At times, on the other hand, there is marked displacement: it may occur in any direction, according to the general position of the bone or bones; sometimes it produces angulation in

the thickness of the limb (common in the upper third of the forearm), sometimes it produces a sort of bayonet deformity (common in the leg); where two bones are involved, displacement often takes the form of convergence between them, if the fracture occurs in the middle of the shafts (in leg and forearm). Finally, a frequent effect is the rotatory displacement of the two ends of the shaft in opposite directions, resulting from the action of antagonistic muscles, exemplifying what Destot described in civil practice as "décalage": this occurs most typically in the forearm, the upper radial fragment being rotated outwards by the supinating effect of the biceps and supinator brevis, while the pronators induce marked pronation in the lower fragment; the phenomenon occurs in some degree, however, almost anywhere.

Over-riding, which is only longitudinal displacement, is never marked except in the arm and thigh. Here, however, it is often considerable, and the opposed fragments are distinctly pointed; the muscles, in spite of their injuries, are still powerful enough to pull the lower fragment forcibly upwards, thus piercing the muscles and carrying with it a few large splinters which remain interposed between the two ends of the shaft. In fractures high up in the thigh, the upper fragment almost always undergoes abduction and external rotation. Similarly in the upper part of the humerus, if the fracture occurs below the insertion of the deltoid, the proximal end is carried upwards, outwards, and backwards, while the lower suffers internal rotation with a variable amount of displacement towards the axilla.

This may be summed up in the following way: whatever the type of fracture, its effects are always very widespread; injury extends much further than might be supposed; in the centre of the injured area is a mass of clots, muscular débris, and free splinters of bone; above and below it are fragments more or less

displaced, but still attached to periosteum or muscle; some, where periosteum has proved resistant and still invests them, retain their position in relation to the shaft, the sharp points of which are generally in contact with those of the opposite side. Fissures in the shaft itself prolong the injury further. Within the medullary canal, part of whose contents is gone completely, is found a mixture of blood-stained pulp and isolated splinters without muscular attachment and destined ultimately to undergo necrosis.

The fractured area is not usually in a straight line; displacement and over-riding, however, are often not serious. All the surrounding muscles are bruised and lacerated, but they still function and approximate again after the missile has passed, completely enclosing the region of the fracture.

## II. Immediate results of Fracture, and the normal course to recovery

Violent local injury producing the effects described above gives rise to a very variable immediate reaction on the system generally.

Some cases show practically none, and exhibit no signs of shock; the patients remain upright and retain consciousness. In the majority of cases it is otherwise, as the initial loss of blood is considerable. At the aid-post and in the field ambulance, hæmorrhage is so profuse that serious vascular injury is instinctively suspected by the less experienced; this explains a good deal of the useless application of tourniquets. Pain and loss of blood combine to produce depression which subsequently disappears if the preliminary steps are taken promptly. Very frequently, too, particularly in fractures of the lower limb and sometimes after very slight loss of blood, severe symptoms of shock are present—pallor, lividity, coldness, and

shivering, sometimes dyspnœa and a feeble rapid pulse —the typical picture of shock.

This is not the result of infection, and does not indicate acute septicæmia, as is sometimes stated; it appears at once, before any infection could have developed, and is, indeed, noticed chiefly in cases which recover without sepsis under suitable treatment; shock is therefore not an evidence of septicæmia. It is apparently the result of sudden vasomotor disturbance following pain reflexes from the wound, of hæmorrhage, and, above all, of sudden injury to branches of the sympathetic system, resulting in violent peripheral vaso-constriction, and corresponding dilatation of the abdominal vessels.

As soon as the pain has passed off and immobility of the injured region has been ensured, the disturbances in the sympathetic system automatically and easily right themselves, producing excellent physiological conditions for spontaneous recovery, should the injury remain aseptic.

There are, in fact, *all necessary elements for rapid callus formation within the wound itself:* an active periosteum, stimulated by the bleeding, enclosing adherent and free bone fragments which are almost comparable to grafted bone, marrow scattered all round the shaft and amongst the muscles and deep cellular tissue, ready to take part in bone formation. In a few days a resistant enclosing belt is formed, within the protection of which the normal processes of repair can continue, as in a simple fracture.

Union is often singularly rapid; I have seen a fractured femur unite in twenty-five days; but the callus is not yet firm at this stage, and can generally be broken down by hand under an anæsthetic. Slowly and little by little its substance becomes definitely organised until the formation of the original bone is reproduced.

Unfortunately such aseptic development is a very

rare exception, occurring only in fractures by bullets which have produced only punctiform skin-wounds. *In other fractures, infection is the rule, and uninterrupted progress with asepsis an exception which should never be relied on, although it sometimes occurs.* For practical purposes it should be assumed that such simple and ideal development never occurs in fractures by fragments of shell, bomb, torpedo or short-range bullets : *war-fractures are almost always infected at the outset.*

Now, without referring to other risks which it involves, infection seriously interferes with the normal progress of union: it is a very frequent cause of pathological callus.

Neither is a united fracture necessarily a cured fracture.

The cure of a fracture requires union by healthy callus with the fragments of the shaft *in line with the normal axis of the limb, so that forces brought to bear on the arm of the lever may produce the usual results, and the physiology of the limb not be affected.* If displacement is not corrected, and the union is anatomically faulty, there is every likelihood that it will be physiologically faulty also, and the word cure in its true sense can hardly be used.

In other words, war-fractures which possess all the elements necessary for prompt recovery, possess too the potentialities of a vicious pathological or faulty union. It is essential to a cure to have an exact understanding of the causes of these pathological developments. Only such knowledge can direct treatment which consistently results in that ideal cure, the only result which repays a systematic endeavour.

### III. Pathological changes in a Fracture

1. **Infection and its results.** — Infection interferes with normal progress by modifying the activity of

osteogenetic tissue, exciting, killing, or inhibiting it. The majority of bad unions result from this. Mechanical factors are much less important.

A. Causes and conditions of Infection.—In practice infection always comes from the outside: it enters with the missile and anything carried in by the latter. Doubtless the condition of the skin is not theoretically without its effect, and it would be absurd to deny the importance of prolonged contact between a fresh wound and the ground or dirty clothing, particularly in wet weather. But these are only secondary causes of sepsis: the spread of infection begins deep, when the skin and subcutaneous tissues are still healthy; it arises below the outer muscular layer, in the spot where the shell-fragment is lodged, with shreds of clothing and pieces of stone and wood which it has carried with it.

Much research during the war has shown that bacterial activity begins around the pieces of clothing between the ninth and tenth hour (Policard). There is nothing on the surface for some time. The point is therefore proved.

*Bacteria concerned.*—The first organisms to multiply are the vibrion septique and B. perfringens (*Aerogenes capsulatus*); between the sixteenth and twenty-fourth hours the streptococci, staphylococci, and pneumococci appear, and thenceforward the flora of any wound remain very complex. In a general way it may be said that any wound is infected in every possible way at the outset, although nothing of this can be determined at that stage.

*Factors controlling the seriousness of an infection.*—Though all fractures are generally infected in much the same way, the results are not always the same. Numerous factors influence the infecting organisms, increasing or modifying their virulence: great variations exist in every group of bacteria, and certain factors which Wright has described may intervene *in*

*situ*. In practice, from the surgical point of view, and particularly in the case of shaft fractures, there are only two definite factors which determine the seriousness of the infection—the *extent of muscular destruction*, and the *existence of anatomical conditions producing complete enclosure*.

Destruction of muscles is a constant feature in the region of the injury, but it varies in extent. Sometimes it is confined to the immediate neighbourhood of the missile's track, and muscles in contact with the bone are uninjured. In any case, and more usually, the injury to muscles is considerable, out of all proportion to the size of the shell-fragment : at a great distance from the seat of the fracture and the track of the missile, muscles are split and destroyed, and vessels are thrombosed ; œdematous infiltration of the periosteum is found where it is least expected. There is wild and indiscriminate destruction, muscle being devitalised so as to produce a perfect medium for bacterial growth. Immediately surrounding the fracture there is little else but muscular débris, and it is in the region of this ready-made incubating area, strewn with foreign débris and shreds of clothing, that the infection develops.

The essential gravity of these cases will be understood, particularly where the track is very oblique and the damage to muscle is consequently very extensive.

These features are most marked in certain regions, the thigh, the neighbourhood of the triceps brachialis, the antero-lateral compartment of the leg, and wherever tough fasciæ completely enclose the muscular bellies. On the other hand, where there is no muscle, the development of severe sepsis is unusual.

Other factors, however, influence the course of the infection.

In fractures of superficial bones, with a widely open wound, the infection is not a serious matter, even if

soil and pieces of clothing are in contact with the broken bones. On the other hand, it is very serious when a deeply seated bone is buried in powerful muscles which enclose the region of the fracture, and where the latter is closely and firmly surrounded to the exclusion of air and light. In other words, the worst infections develop where a completely enclosed area is produced. This fundamental proposition is a clinical fact which it would be idle to substantiate ; it is not original ; the classical term " débridement," which describes the essential process of war surgery, in itself proves how old this clinical axiom is.

Again, this enclosed area favourable to sepsis is quickly reinforced by it : from the earliest stages of protective reaction, even before infection has begun to develop, the rigidity of the injured area increases, the swollen and œdematous muscle closing more completely than ever the region of osseous and muscular destruction, which becomes a perfect incubator : to the favourable anatomical conditions of enclosure, pathological conditions are added, and the development becomes still more rapid, and hourly more formidable and dangerous.

B. Results of Infection.—If clearance and exposure of the region are not rapidly effected, sepsis produces most serious anatomical and clinical results ; sometimes death ensues so rapidly that the spread of sepsis has hardly time to develop and its anatomical results are negligible ; more frequently things are otherwise, and the local effects of sepsis control the clinical progress of the fracture.

I shall divide these results into three main classes :—

1. *Septicæmia.*—Theoretically, the rapid development of infection in a wound presenting a large absorbing surface may be followed by acute septicæmia. In practice it is very rare, and septicæmia is not encountered. So far, it has scarcely been proved by bacteriological methods : blood-cultures, though frequently

made, have very rarely given any results, except in the last moments of life, and clinically, rapid deaths, sometimes attributed to very severe septicæmia, are much more probably caused by the absorption of toxic products of muscular necrosis which plays so important a part in influencing the earlier symptoms.

The proof of this is that thorough cleansing of the area and the surgical removal of all devitalised tissue (the latter augmenting the absorbent surface and poisoning effect) abolish all evidence and likelihood of toxæmia, after which secondary visceral lesions, such as would certainly appear had there been a general infection from the outset, are never seen.

2. *Gas gangrene.*—This is the most formidable and common infection which develops in fractured areas. It is not usually a septicæmia ; in spite of the gravity of the general symptoms the initial lesion is definitely localised. So large a number of bacteriological and clinical forms have been described that it is difficult to know where one is. In my opinion, it is the anatomical localisation of the primary focus of infection, and not any specific form of organism, that really determines the clinical form of the affection ; phlegmonous erysipelas, diffuse gaseous cellulitis, or true gas gangrene arise according as the infection is cutaneous, subcutaneous, or deep in the muscles. In fractures the deep form is usually found, that is to say, true gas gangrene, rapidly progressing and soon complete.

The fracture itself is not responsible for this ; it is the muscular injuries in an enclosed area which are the primary factor in the infective development. Injured bone plays no part except in augmenting muscular injury (laceration by scattered splinters), and in contributing to produce necessary local conditions by detaching muscles from their insertions.

Gas gangrene is not a mysterious phenomenon whose pernicious effects are not to be escaped from : it should be regarded as a gangrene, chiefly mechanical in origin

resulting from interference with the blood-supply, of otherwise healthy muscular tissue, this effect being due to the pressure of gas produced by histolytic organisms in a closed muscular wound,* or by the disintegration of muscle. Amongst the organisms found in such an injury, a certain number, or at least B. aerogenes capsulatus, are capable of producing gas, and it appears that the disintegration of muscle favours this process. The gases in themselves are not poisonous; their pressure is merely evidence of bacterial activity. If the wound is closed, it cannot escape, and spreads into the sheaths of the muscles surrounding its incubating chamber. The distension which follows closes the deep wound even more firmly, and blocks every way of escape; the pressure increases fatally; capillaries are compressed, and the circulation, even in parts which are still unaffected, is stopped, and in this way an acute gangrene is mechanically produced in the infected area.

Owing to the fascicular arrangement of the muscles, the progress of the gas continues, causing extension of the gangrene, whose products of decomposition are absorbed, causing serious toxæmia which presents the clinical features of septicæmia.

There may be other forms of gaseous infection, but I believe that true gas gangrene complicating fractures is almost always a gangrene produced mechanically by impaired circulation, gas under pressure directly causing obliteration of capillaries and producing gangrene which results in death from toxæmia.

In brief, gas gangrene, or rather gangrene caused by gas, is a purely local complication of the infection of muscular wounds accompanying fractures. And local treatment, if sufficiently comprehensive to clear out the area of muscular destruction including the closed

* The bacteriological researches of Kenneth Taylor confirm at all points the theories developed here of the mode of action of gas gangrene.

cavity, is always sufficient prevention, should signs of the infection appear early.

3. *Osteomyelitis and its results : the pathology of the Callus.*—Infection of the bone is the most characteristic complication in fractures which have escaped the formidable consequences of muscular infection in a closed cavity (gangrene caused by gas).

Direct infection of the seat of the fracture and of the bone-marrow is a constant feature of all fractures where asepsis has not been ensured by operative interference. Bacteria find the conditions here the more favourable since there are more clots, muscular débris and fine bone particles in contact with the shell fragments and scraps of clothing, since large splinters surround the area, since more fissures exist, and finally since the wound is less directly open to the exterior.

At any rate, the ends of the bone, bruised, and affected by traumatic osteitis, as the older writers called it, rapidly become infected ; suppuration begins on their surface, at first slight, but later more and more profuse, the first result of which is to precipitate the necrosis of any parts whose vitality is diminished, the structures thus necrosed further helping to increase suppuration.

(*a*) *Free fragments*, which in a clean wound would have been so many active grafts, rapidly become sequestra which suppuration tends to eliminate.

*Partly detached splinters*, which only retain slight vascular connections with bone and muscles, lose these by thrombosis of their vessels, and become so many fresh sequestra whose presence stimulates infection and largely augments pus-formation. This spreads along the extremities of the shaft, and a regular vicious circle is introduced, suppuration increasing in order to eliminate débris the necrosis of which it has itself produced.

*Firmly adherent splinters*, whose vitality at first appeared sufficient, rapidly become diseased under the

influence of sepsis; the infection spreads along the fissures bounding them, involving them in a continuous layer of leucocytes, which soon develop into fleshy granulations; their presence obstructs vessels and displaces the fragments, to such an extent that soon they are nothing more than fragments of inflamed bone; they are rough to the touch, with periosteal new deposits on their surfaces, not dead white like traumatic sequestra, but showing red patches as in sequestra from osteitis; these splinters slowly die.

It is true that this is not always so; there are many adherent splinters which resist infection and become incorporated in the callus, but the reverse is much more common. In all fractures which have been insufficiently cleared out, and have suppurated for any length of time, osteitis in the adherent fragments is the rule. The majority work out sooner or later; the others remain diseased, and cause the persistence of sinuses, with considerable pain at the level of the fracture. Apart from fractures by shrapnel, and a few favourable cases by shell-fragments, it could almost be said that the only difference between free and adherent splinters lies in the length of time elapsing before they make their way out. In any case there are numbers of wounded at the bases who collect in a box the splinters which their medical officer has carefully preserved, and which have come to the surface in the pus. Exaggeration, however, must be avoided. The one important fact to remember is that in septic wounds which are not speedily cleansed, few splinters escape osteitis.

Sepsis has also a deleterious effect on all the constituents of the broken shaft.

(*b*) *The bone-marrow*, biologically the most delicate of them, is the first to be affected and killed; it is invariably affected to some extent.

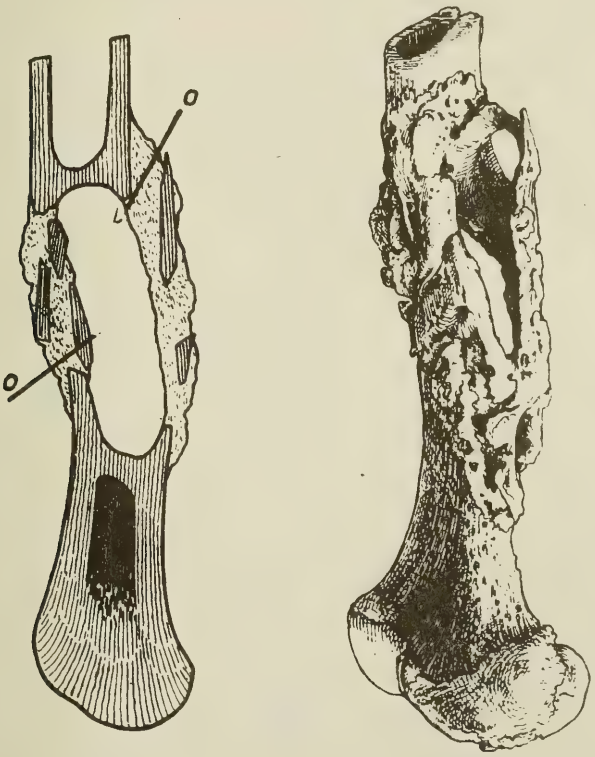
During the early stages of less serious cases, this is evidenced by the formation of a purplish protrusion

blocking the medullary canal; this plug does not bleed, and is easily displaced by the finger, leaving a marked hollow space in the canal. This is seen well in X-ray photographs; the medullary cavity above and below the fractured area is apparently empty, seeming more translucent than the rest of the bone.

When the sepsis is more marked, medullary infection spreads much further, sometimes traversing the whole length of the shaft, even reaching the epiphysis; infection of the joint sometimes occurs along some unusual track.

Later the disease and death of the marrow are evidenced by the formation of more or less considerable sequestra from the ends of the shaft. It occurs in this way: where the medullary plug is formed the vessels are obliterated, some of them supply the compact bone surrounding the medullary canal and the destruction of these vessels leads to necrosis of the whole circumference of the bone. On examination, a sequestrum is found in the form of a regularly serrated ring; the projections are formed at the expense of the bone enclosing the medullary cavity in the whole of its circumference. Later this sequestrum breaks up into numerous jagged and irregular pieces which have no characteristic appearance. This *formation of pseudo-fragments as a result of osteitis of the ends of the shaft* should be well understood. The fragments are not traumatic splinters, but sequestra produced by medullary infection, or osteomyelitis in the true sense of the term. They work out gradually if the callus has not already formed, and sometimes the osteitis disappears, but much more often, when the infection of the bone marrow is more serious and extensive, the results are entirely different; the marrow being destroyed for a great distance, a more or less extensive cavity remains in the centre of the embryonic callus, which is not filled up by anything, and the periosteum, still adherent to splinters displaced by the injury, forms

a callus outside the long axis of the shaft. During this time the marrow, proliferating outside the area of medullary destruction, forms a plug of condensing osteitis which entirely shuts off the medullary




FIGS. 8 and 9.—Sketch of a femur amputated after the fracture, which had not been subjected to sub-periosteal esquillectomy, and had suppurated for nine months. It will be noticed that the callus extends beyond the shaft (*i.e.* is wider), that it surrounds a hollow cavity, and that ossification occurring round adherent splinters has left an infected cavity whose obliteration is impossible. In the diagram the medullary canal is seen to be closed at each end, and there are two openings (o). After nine months, suppurative arthritis developed in the knee-joint.

canal. Thenceforward the cavity is closed and bounded by rigid and inextensible walls, a condition which is intrinsically incurable, none of the walls

being able to come into contact with one another. At each end of this cavity, in which infection persists, the diseased ends of the shaft continue to produce inflammatory sequestra, whose presence promotes continued suppuration.

Cases are thus seen with a large callus completely surrounding a closed infected area, with no outlet to the exterior except sinuses which cannot be cleansed.

Sometimes closure of the external wound occurs after removal or elimination of a sequestrum, but a fresh sinus soon develops, showing that another sequestrum has formed and, being imprisoned, tries to escape.

The track of a fistula through the soft parts is hard and lardaceous, and its walls are not elastic. Outside, round the external opening, the skin is purplish and shining. There is a tendency for cicatrisation to spread up the opening, and sometimes actual tunnels of epidermis, 2½ inches in length, are removed, but cure is still far distant, such cases being doomed to a succession of operative interferences without any guarantee of a satisfactory ultimate recovery.

This is a course frequently taken by disease of the bone-marrow, but it is not the only course.

Sometimes when the medullary canal has been exposed by the missile (and particularly, I have found, when the continuity of the shaft has not been broken), a condensing osteitis appears which thickens the bone enormously and tends to obliterate the medullary canal, the bone becoming as dense as in a case of rickets. This large ivory-like mass is often the seat of a peripheral osteitis: eroding abscesses are formed which can be cured by small incisions, leaving a limb riddled with scars, with stiff sclerosed muscles, hardened fasciæ, and thrombosis in many of the smaller vessels.

X-rays show a compact mass, in which no structural details are visible. This is seen in the femur and

tibia; at least I have not seen it elsewhere. Its pathological anatomy is best studied in the tibia; here condensing osteitis, causing hypertrophy of the bone, mechanically prevents the healing of the stiff and lardaceous surrounding parts. Deep grooves must be gouged in the dense bone, great quantities being removed before there is even a chance of healing. These bones, recalling those seen in long-standing osteomyelitis, are sometimes found after being gouged out to enclose a metallic fragment in the centre of the mass.

(*c*) *The periosteum* is more resistant to infection than the bone-marrow. A small part of it at the ends of the shaft undergoes necrosis, baring the ends of bone in the wound. This is of no great importance unless the marrow is also destroyed, but should it be so, the periosteal infection facilitates the formation of the ring sequestrum of medullary origin described above.

As a rule the infection which destroys the marrow-cells stimulates periosteal activity. But the normal physiological activity of the bone-forming tissue is disorganised, and large masses of unhealthy bone are formed; the normal position of the active periosteum being upset by splintering, it forms a misshapen callus, which, as we have seen, frequently surrounds a totally empty medullary cavity. This is the true classical external callus abnormally developed. Nothing will replace it, since no ossification from within (*i.e.* from the marrow) is possible. Hence the appearance of all the large calluses—multilocular with a central cavity—which are so frequently seen. Inside this cavity there are soft granulations, sometimes fragments of metal, often a bell-shaped sequestrum which is merely a splinter pushed into the medullary canal at the time of the injury, which suppuration has not been able to eliminate. Later on there are sequestra produced by osteitis from the ends of the shaft.

Briefly in these cases sepsis results in destruction of the marrow and disease of the periosteum the effects of which it will be very difficult to remedy later.

Sometimes a severer or more lasting infection succeeds in inhibiting all activity of the periosteal bone-

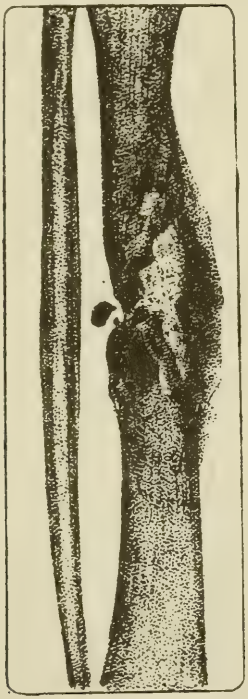


FIG. 10.—Typical medullary cavity with a large periosteal callus after union of a shell-fragment fracture which had not been cleared by operation. The sinus persisted for sixteen months, although scraped clear on three occasions. The case was cured by esquillectomy with levelling of the bony walls.

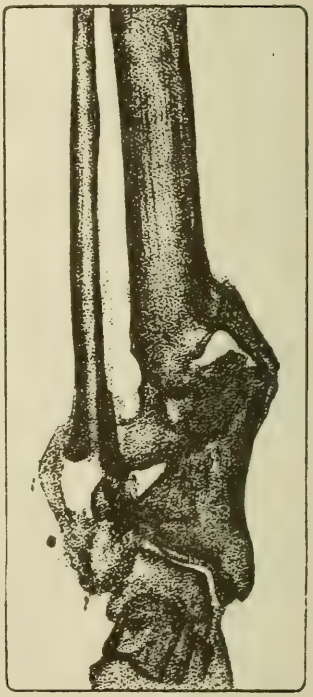


FIG. 11.—Multilocular and multifistular callus (with four centres of suppuration) photographed after seven months' suppuration. All the splinters had been deliberately left to aid bone-formation. Resection of the callus followed by osteosynthesis gave good results, but marked shortening.

forming tissue, just as it has destroyed that of the marrow; after the spontaneous elimination of sequestra, nothing is left between the rarefied and atrophied

ends of the shaft but soft tissue of no definite structure. The death of the osteogenetic cells, without any interposition of muscle between the bone ends or without esquillectomy, eventually produces a definite pseudarthrosis which is extremely difficult to

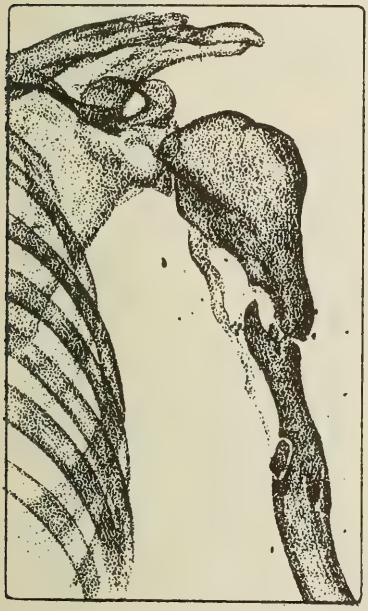


FIG. 12.—Callus with a large cavity beneath the periosteal bone, in which are recurring sequestra caused by osteitis of the shaft. The case, in which subperiosteal esquillectomy had not been practised, recovered at the end of eighteen months after six operations with ankylosis of the shoulder due to suppurative arthritis.

FIG. 13.—Spontaneous pseudarthrosis after profuse suppuration and the elimination of many sequestra. No operation on the bone had been performed. Cure was obtained by metallic osteo-synthesis. The persistence of displaced sequestra will be noticed in this photograph.

cure, since all power of local bone-formation is lost. Numerous examples are seen in all the long bones except the femur. Almost all the false joints upon which I have operated were caused in this way.

To recapitulate,—*infection is fatal to the vitality of bone-fragments and bone-forming tissue; it destroys the marrow, and inhibits or seriously interferes with periosteal activity; it produces misshapen callus, osteomyelitis, and pseudarthrosis. It is to be feared above everything else.*

Besides these deplorable local effects, infection produces effects equally serious in the bone itself at some distance from the fracture, owing to the frequent existence of *fissures*.

These fissures, unimportant in an aseptic or immediately disinfected wound, seriously affect the prognosis should any suppuration set in. The infection spreads along the fissures to a great distance from the fracture, inducing diffuse osteomyelitis of the shaft or sub-chondral articular osteitis which soon affects the joint and results in serious infection of the latter. In this way suppurative arthritis appears after about ten days in cases of sub-epiphyseal fracture of the upper part of the humerus, or suppurative arthritis of the knee-joint after supra-condylar fracture of the femur; this arthritis necessitates secondary amputations which are not always successful in saving life.

Some of these fissures are visible under X-rays, but more usually they are not distinguishable in the negative, particularly in the epiphyses. Some quite extensive fissures are imperceptible on direct examination, and are only recognised in a transverse section of the bone. This explains the possibility of late secondary arthritis after the ankle has been brought to a right angle under an anæsthetic, for instance. In any case, the frequency of these grave complications necessitates thorough operative disinfection of the main fractured area if they are to be avoided.

Infection may reach *joints* in other ways: in very virulent infections, when no fissures exist, suppurative arthritis sometimes develops rapidly; the medullary canal is full of pus; a widespread diffuse osteomyelitis

has supervened, and the prognosis is extremely grave. In section one can clearly see the track along which infection has spread through the cancellous tissue, generally from a splinter within the canal.

Spread of infection may also occur along the compact bone beneath the periosteum, but this is much less common.

Infection is not merely dangerous to bone elements; persistent suppuration has serious effects on the surrounding soft tissues. Tracks of pus develop along muscles, infiltrate muscular sheaths, necrose tendons and fasciæ, and often find outlet at a great distance from the wound. Sclerosis of muscles and thickening of fasciæ follow, the final result always being marked diminution of the functional value of the limb. This is particularly deplorable in the neighbourhood of joints, as stiffness follows, with ligamentous shortening which it is difficult to remedy later.

When suppuration is set up in the neighbourhood of *large vessels*, it is not a question of remote risk, but immediate serious complications may occur. Vessels are undoubtedly very resistant to suppuration round them. It is commonly believed that arteries may be found crossing a large purulent area like a cord, and remaining intact. But this can only occur if an artery is absolutely healthy. If the projectile in passing, or any splinters which it has scattered, happen to injure the artery, sudden secondary hæmorrhage may occur later. The bruised patch, which would have healed easily in aseptic surroundings, gradually undergoes necrosis, and this ulcerated patch is suddenly forced out, causing violent hæmorrhage. The presence of splinters in contact with a vessel, as seen notably in the thigh, facilitates the occurrence of this complication.

Sepsis has little effect on *nerves*, unless they are involved in the original injury. But as in the case of arteries, if a nerve has once been crushed or severed,

and its two ends are in contact with a purulent area for a considerable length of time, healing of the injury is an extremely difficult matter. Hard and dense tissue forms round it which prevents spontaneous regeneration and greatly impedes surgical interference.

2. **Faulty Union** (anatomical and physiological).—Consolidation may be seriously impeded or even actually arrested by certain anatomical causes, the persistence of which usually results in a vicious union.

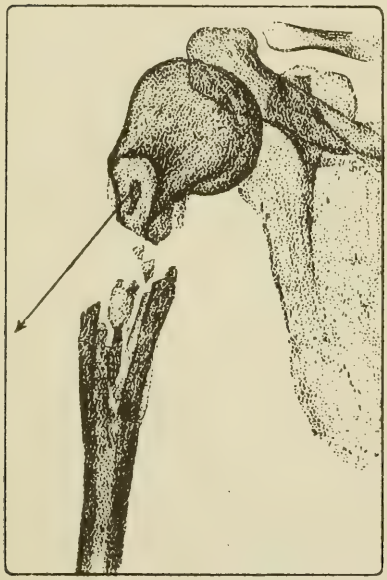


FIG. 14.—Pseudarthrosis of the humerus due to failure in reduction.

War fractures undoubtedly undergo less marked displacement than those seen in civil life, since the lacerated muscles pull less strongly on the fragments, but there are certain constant displacements where non-reduction entails serious results. Persistent infection with suppuration in the region of the fracture render the latter liable to incomplete reduction, both at first because œdema and swelling of the injured limb prevent its being set easily, and later because the frequent dressing of it for months necessitated by suppuration, render it difficult to maintain absolute immobility.

Callus formation is hindered by *antero-posterior displacement*: thus in certain fractures of the thigh, the upper fragment tends to tilt forwards, while the lower is pulled backwards: without referring to the various effects of muscular action in such cases, it will be

obvious that the formation of a callus is scarcely encouraged by the persistence of wide separation.

*Longitudinal displacement* or *over-riding* is a still more awkward matter; it is particularly frequent in the thigh and arm. Unless it is reduced, union can only occur by the formation of a lateral periosteal bridge, producing a bayonet-shaped callus which alters the axis of the limb and leads to marked shortening.

*Lateral displacement* occurs particularly in the neighbourhood of epiphyses and in fractures near joints, frequently giving rise to pseudarthrosis, notably in the humerus and femur: at the shoulder and in the sub-trochanteric region, the upper fragment is maintained in a position of marked abduction by the external rotators inserted in it (connecting the scapula and tuberosities in one case, and the pelvis and the trochanter in the other), while the lower fragment is pulled inwards and upwards by the adductors and internal rotators; approximation of the two fragments is impossible. It is absolutely essential for satisfactory consolidation to bring the lower fragment, the only movable of the

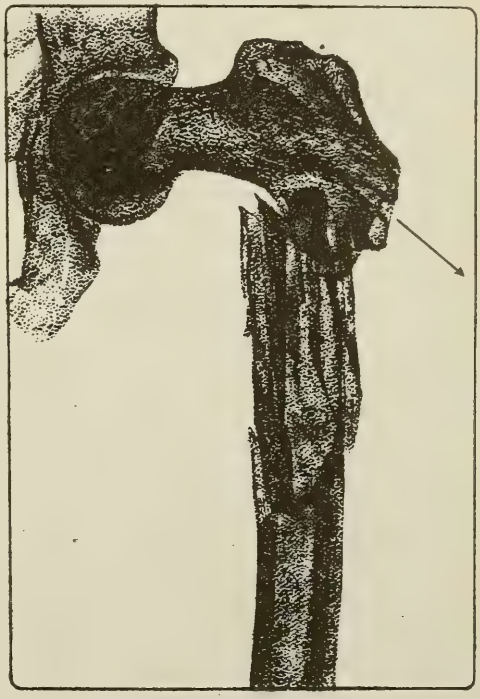


FIG. 15.—Pseudarthrosis of the femur due to failure in reduction.

two, into line with the other; unless this precaution is taken, pseudarthrosis is favoured, and if union occurs, it does so in a faulty position which interferes with the functions of the limb.

*Displacement by rotation* is possible in all bones, but it is most frequent and serious in the forearm. The upper fragment assumes a position of supination under the action of the biceps and supinator brevis, while the lower is fixed in pronation by gravity and the pronator quadratus. Thenceforward, to use the expression brought into general use by Destot, the bones are " décalés " (deprived of support), and the physiology of the hand movements is seriously interfered with.

*Displacement in the line of the bone* causes angulation of the fragments, and may occur everywhere, but particularly in the forearm and the leg; the V-shaped consolidation which results is particularly unsound, and, in the lower limb perhaps more than elsewhere, gives rise to marked deformity.

In brief, the various displacements possible in a fracture result in interfering with the formation of the calius by separating the fragments, or by allowing one to form in a faulty position which will deprive the limb of a large part of its functional value.

Correct treatment does not consist only in the maintenance of asepsis: *no fracture is really cured unless the fragments are united by a healthy callus in line with the normal axis of the shaft, so that forces acting on the arm of the lever may be exercised normally and have a normal physiological action.*

Treatment which is intended to restore normal conditions should be directed towards this object.

## CHAPTER XI

## GENERAL PRINCIPLES IN THE CONSERVATIVE TREATMENT OF FRACTURES

For reasons already outlined, it follows that in modern war fractures, other than those by bullets with punctiform wounds,* treatment to reproduce original conditions must involve three essential features: *disinfection*, *reduction*, and *immobilisation*, which are necessary for the production of regular union in a straight line by a healthy callus.

But the order in which these three parts of the treatment are taken in hand is not a matter of indifference: it has often been said during the present war that reduction and immobilisation are the main points in treatment, and if well realised, by reducing the intensity of infection and the difficulty of treating it, limit the scope of the operation required, thereby reducing this to the category of a secondary intervention.

In my opinion *this is a serious clinical mistake*: undoubtedly immobilisation is at the root of all treatment directed against inflammation, and sepsis developing in a fracture is certainly more serious if the fracture is badly reduced or not immobilised. But this is only one side of the question of the causation and treatment of infection in war: the most complete immobility in the world and the speediest reduction will not prevent the development of gas gangrene if the wound is not suitably opened up, nor will it prevent the appearance of acute osteomyelitis, connected with

* I repeat that extensive crushing justifying amputation is not discussed here.

the presence of infected clothing and débris in the medullary canal.

In regarding immobilisation as the salient point in treating fractures caused by shell-fragments, a great risk is run for which nothing can compensate: no reliance should be placed on stereotyped formulæ; it should be realised that the *essential and fundamental process in the treatment of all fractures, on which depend the patient's future, at first his life, subsequently the safety of his limb, and ultimately its functioning power, is early and immediate cleansing: every fracture*, apart from the exceptions above-mentioned, *should be so treated, as early as possible, that its subsequent course may be aseptic*, in order that no infection may inhibit the bone-forming tissues which effect repair.

The other elements of the treatment should follow this and not precede it: their proper function is to control the formation of callus, and to ensure that union follows in a straight line: they are the easier to carry out the more regular the progress of the wound, that is, the earlier, more careful and complete the operative cleaning which has been practised. Reduction and immobilisation are only supplementary to the operation; they should follow, and not precede it.

With this in view, I shall discuss:—

1. The disinfection of fractures by operation.
2. Reduction.
3. Immobilisation.

### I. Operative Disinfection of Open Fractures *

This should be considered in two categories:—

In (*a*) the wound is seen in the first few hours,† previous to any clinical sign of infection.

* I use this term once more to exclude bullet fractures with punctiform skin wounds, which should be classed, as I have said, as simple fractures.

† Theoretically this means in the first twelve hours; practically, in the first twenty-four.

In (*b*) the wound is seen after the appearance of symptoms of infection.

**A. Initial operative disinfection of fractures in the first few hours : exploratory and prophylactic esquillectomy.**

1. The Principle.—Like all war-wounds, fractures should be treated by operation as speedily as possible, in order to ensure complete prevention, at the outset, of any acute or chronic infection which threatens the injured region. There being no means in the earliest stages of distinguishing seriously infected from only slightly infected fractures, all should receive the same preventive treatment without distinction.

This principle of general disinfective action is at the root of all prophylaxis.

It is essential, therefore, in any individual case, as in all wounds of war, at once, *even if not the slightest sign of infection has appeared*, to remove any foreign bodies in the wound, scraps of clothing, tissue destroyed by the injury or liable to necrosis following infection : the wound after such treatment should be clean, containing no suspicious elements or recesses where infection may develop. Everything contused or lacerated should be exposed thoroughly.

*The operation required is not a mere matter of drainage* (*e.g.* widening the entry and exit wounds to introduce drainage tubes, after a rough cleaning of the soft parts), *nor should it be limited to partial and prudent removal of a few isolated fragments dictated by a groundless fear of pseudarthrosis ; still less should it be a rapid and indiscriminate scraping of the fractured area, bringing out everything that the instrument encounters as it is withdrawn.*

*The danger lies in the medullary canal.*

*This particularly should be laid widely open by a methodical operation consistent with the main principles of preventive disinfection of war-wounds, allowing of*

*complete exploration of the area, and of any necessary excisions.*

*With this object, the operation should be conducted in the following way, under a general anæsthetic and after radiography if possible, for the ideal is to approach the fracture with an exact knowledge of its structural details.*

*A long and carefully placed incision is made, to facilitate, first, the removal with bistoury and forceps of any soft tissues which are contused or crushed; a search is then made for foreign bodies: in brief, nothing should be left in the region of the fracture which will infect it or encourage infection to develop.*

*This done, all free splinters which have been forced into muscles must be removed with great care. Patient and minute search is required, not a hasty clearance. Next, the region of adherent splinters is approached, and such are removed as appear to interfere with exploration and thorough display of the medullary cavity.*

At the end of the operation the medullary cavity should present roughly the appearance of a groove in cases of fractures with large splinters, a funnel in fractures with one large short splinter, and entire loss of substance in a many-splintered fracture. In the unusual event of a transverse fracture, where there are no splinters, about ½ inch should be resected from each end of the shaft, as the latter are contused and devitalised by the violence of impact.

Nothing, in fact, about which there is any suspicion, nothing which can favour infection, should be left in the neighbourhood of the fracture, so that infection may not interfere with union by causing necrosis of the osteogenetic elements in the marrow and periosteum.

2. ADVANTAGES.—*This wide esquillectomy, the sole means of obtaining a detailed knowledge of the injury, is a preventive step, since it removes all unknown factors from the wound.*

(*a*) *It absolutely prevents the development and conse-*

*quences of serious sepsis.*—If these appear it means that the operation was badly or only partially done. No proof of this is needed beyond the fact that the operation is intended to remove anything calculated to produce sepsis or to favour its development.

All who have performed this operation are unanimous in declaring that it has enabled them to avoid gas gangrene and acute osteomyelitis; others who first criticised it have ultimately declared in its favour.

For my own part, I have practised it systematically since the month of August 1914, according to the principles and methods of my teacher, Poncet. I am doing practically the same now as I have done from the beginning, without introducing any new feature. In this way I have been able to cure more than 250 comminuted shaft fractures with the loss of only one case, without a single case of gas gangrene; and with only one case (which proved fatal) in which persistent sepsis necessitated amputation.*

Supplementary proof is easy: at the front the surgeon has only to reckon the number of his secondary amputations for fracture; at the base he has merely to question these men, and he will find that the majority of these amputations were necessitated by fracture, and that in almost every case the amputation was secondary.

It may be said that, in an ambulance unit at the front, the number of secondary amputations is inversely proportional to the number and extent of early esquillectomy operations.

Further, if need be, the question can be decided by studying the development of each surgeon's personal views; the number favouring this operation on principle has become considerable, and each recommends a more and more comprehensive operation. At first, in August 1914 and early in 1915, we were very few

* Esquillectomy was performed on the third day after sepsis had fully developed.

and very much criticised; everything that I have since seen and done has shown me that we were right.

In brief, after twenty-two months of war, it must be acknowledged that wide and early esquillectomy is an absolute protection against the serious infections which endanger the life, or at least the limb, of every case of fracture, and that it *alone* will give this result.

(*b*) But that is not the only advantage of this method: immediate complete esquillectomy, by allowing of complete investigation of the wound, also ensures the prevention of all the slight chronic infections whose secondary effects are so prone to prevent a satisfactory union of the fractured bones. By it all foreign bodies, all tissue débris condemned to necrosis, are removed at once. This avoids the occurrence of that persistent suppuration which, sometimes destroying marrow and periosteum, leads to pseudarthrosis, sometimes, by irritating the periosteum and disturbing its osteogenetic activity, eventually produces a pathological callus, within which infection produces necrosis of the ends of the shaft and causes persistent osteitis.

A radical esquillectomy entirely exposes the medullary canal, which is often filled with small fragments and metallic or other particles; without it, these cannot be removed, and osteomyelitis is certain; sometimes it is acute, sometimes chronic from the beginning. It can only be avoided by completely cleaning the area of destruction in the shaft.

In the large number of shaft fracture cases which I followed until cure, there were only about ten in which a sinus persisted. This always occurred in wounds in which I had thought it well to leave one or two fragments, apparently firmly adherent and well supplied with blood; in these, removal of the fragments stopped the discharge. There were very few amongst my cases in which a late abscess developed (after a year or more), whereas this is usually very frequent; the two or three which I have seen have

appeared in cases upon which I had operated too late to prevent serious sepsis. Anyone who knows the appalling amount of osteitis, osteomyelitis, and cases of persistent sinus which fill our military hospitals at the present time will not for a moment question the enormous advantage of avoiding the terrible consequences of early infection.

3. Criticisms of this Operation.—Free prophylactic esquillectomy is not, however, practised everywhere. Many surgeons are afraid of it, and assert that it predisposes to pseudarthrosis.

(*a*) *It is useless*, they say, *because many fractures unite without such immediate operation if they are properly immobilised*, and because, if it prove necessary, a secondary and limited esquillectomy, not interfering with any adherent fragments, is almost always sufficient. Later, if necessary, the surgeon is free to search for any enclosed sequestrum, but interference should be limited to this, and this is better than a flail-limb after removal of an excessive quantity of bone.

Thus described it seems natural, and even wise, to refrain. But is this a true statement of the case? This supposed harmlessness of war-fractures has scarcely been seen except at the bases, where the question cannot rightly be judged. A man must go to the front to appreciate truly the seriousness of fractures by shell- or bomb-fragments. Now even at the present day, after twenty-two months of war, this is what is to be seen there: wherever free esquillectomy is not carried out early and systematically, before any clinical sign of infection, cases of gas gangrene and serious osteomyelitis have still to be battled with, there are deaths from sepsis, and early secondary amputations for infected fractures. On the other hand, where esquillectomy is a general rule, there is no gas gangrene, and no dangerous sepsis except in cases already developing it on arrival; fracture cases

explored early run an aseptic course, and no secondary amputations for septic fractures are performed.

Early free esquillectomy or frequent secondary amputations—the question can be expressed in no other way—and it is this fact which must be realised by anyone who wishes to get to the root of the matter.

In the base hospitals it is a different matter: unoperated fractures arriving twenty-four or forty-eight hours after evacuation are more often caused by bullet wounds, punctiform at entry and exit (whose habitually aseptic course everyone knows), or by shrapnel bullet (whose comparative benignity is frequent). Unoperated shell-fragment cases are more and more rare, for the simple reason that surgeons at the front, better aware of the serious danger which these cases run, do not send them further until the initial esquillectomy has been performed.

(*b*) *But*, it will be said, *why advocate so sweeping an interference? Why not limit it to the removal of free splinters, leaving those which are adherent and living?* Would it not be better to retain everything which appears likely to live, leaving it to Nature to decide what she wishes to retain and what to reject?

This would obviously be the ideal course if there were not certain disadvantages in relying so much on Nature. These disadvantages are the following:

(i) *Serious infection cannot be prevented except by a complete clearance*, leaving nothing suspicious in the wound, which should be mechanically disinfected throughout. If adherent fragments are left undisturbed, how are scraps of clothing to be discovered, caught on the points of the shaft, embedded firmly in the cancellous tissue of some adherent splinters bordering on the track of the missile? How are those isolated splinters to be removed which have penetrated the medullary canal, and are about to undergo necrosis in an already injured region, thus giving rise to serious osteomyelitis, sometimes to interminable suppuration? Wide clear-

ance will ensure sufficient exploration of the fracture to guarantee satisfactory development and repair.

This is well shown by what is found in the wound during a second operation to complete an originally insufficient esquillectomy; in one in three cases fragments of clothing are still found enclosed in it (see fig. 16).

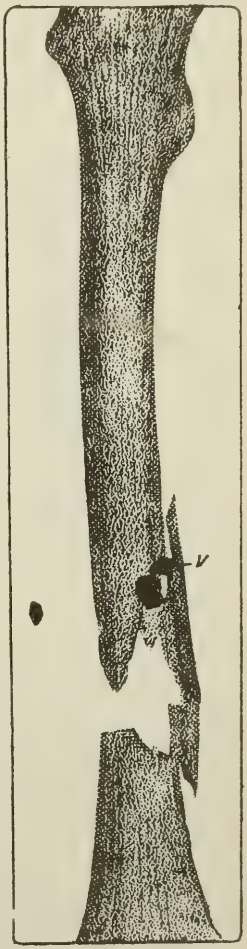


FIG. 16.—Fracture of the femur after incomplete esquillectomy at the front. On the eighth day, when I first saw the case, suppuration was profuse. I removed the large remaining fragment, leaving the periosteum, thereby discovering and removing a shell-fragment and a fetid mass of clothing material rammed high up the medullary canal, which could not have been discovered without esquillectomy. This was sufficient to stop the suppuration; there was no further pyrexia, and on the thirty-fifth day the patient could raise the thigh.

(ii) *Without esquillectomy, the prevention of chronic infection cannot be depended upon* (and this certainty is essential); a fracture not entirely cleaned will suppurate; this suppuration, which is almost always difficult to stop, will produce the troublesome effects described above, on the ends of the shaft and on the marrow; this should be avoided at all costs, for *anything is better than chronic osteomyelitis of the callus, which may persist for any length of time.* Not enough thought is given to the life which those suffering from osteomyelitis are fated to lead in the future, with continued pain, sinuses constantly reappearing, necessitating repeated operations which they must

undergo without ever knowing how far away is the promised cure, or whether amputation will not eventually be necessary. Surely it is worth while to take any trouble that will save this long martyrdom.

FIG. 17.—Radiograph showing the presence of fragments in the medullary canal; the wound had suppurated at the front for two months, and amputation had to be performed.

This can easily be done without endangering the future solidity of the bone.

Esquillectomy, which protects from everything giving rise to disease of the callus, if properly carried out, should leave in the wound thus disinfected by mechanical means all the elements necessary for speedy union.

(c) *It is also true that certain surgeons have criticised the method by stating that it predisposes to pseudarthrosis*, but their opinion scarcely deserves credit. With no experience of surgery at the front, they have been appalled by certain very extensive removals of bone practised there, in some cases by the careless and ignorant, in others by more experienced surgeons who refused to amputate an arm for enormous injuries when the nerves and vessels were intact.

Ordinary cases are different, and we may once and for all dismiss that dread of pseudarthrosis which has so often prevented necessary steps from being taken; disregarding deliberate removal of bone to avoid disarticulation or amputation, which should not be considered in this connection, it may be stated dogmatically that *pseudarthrosis seen in base hospitals is almost always the result of prolonged sepsis, and not of too free an esquillectomy.*

Speaking practically and theoretically, pseudarthrosis, in the cases studied here, where the interposition of muscle is extremely rare, can only point to one of two equally bad and equally avoidable things—a mere partial esquillectomy, allowing of an infection which destroyed the bone-forming elements in the region, or a technically faulty clearance, which did not leave the latter in place in the wound which it had cleaned.

Now, free esquillectomy does not mean technically faulty esquillectomy. The only technically faulty one is that which, backed by no physiological idea, tears away the fragments which are to be removed, careless of leaving in the wound the fertile tissue of the bone which alone assures the formation of a regular callus.

This fertile tissue is found only between the fibrous layer of the periosteum and the shaft. Ollier conclusively proved its osteogenetic value; by its action the periosteum manufactures bone, with equal ease whether it be young, or irritated by injury or slight infection; but to leave it in the wound, a sharp rugine must be used to separate it from the dense bone to which it adheres; this is essential.

All surgeons who have experimented under the same conditions as Ollier, all those who, like him, have understood, and searched in the periosteum beneath the fibrous layer for the deeper osteogenetically active layer, have got the experimental and clinical results which he described.

Hence it should theoretically be admitted that thorough sub-periosteal esquillectomy with a sharp rugine leaves in place the bone-forming elements which should be sufficient to re-establish continuity of the bone.

It is so in practice; surgeons taught to respect the periosteum have obtained results during the present war which are the best experimental and clinical proof of Ollier's theories that could be adduced. It is thus proved that the only operation justifiable is one

which preserves in the wound the fertile, as well as the fibrous, periosteum.

A well-executed esquillectomy is not simply one which checks infection; it is actually and only that which, taking the necessary preventive steps, leaves in the wound, undisturbed by any pernicious infection, the periosteal bone-forming elements which will eventually form a regular callus: *only a thoroughly sub-periosteal esquillectomy is justified.*

The question is, then, a simple one: esquillectomy followed by pseudarthrosis is a badly executed esquillectomy. *Early sub-periosteal removal of fragments under ordinary operative conditions does not expose the fracture to the danger of pseudarthrosis, and such an operation is conducive to rapid recovery and is physiologically justified.*

*Further, it should be understood that the original esquillectomy is not a resection of the entire circumference of the bone; it is not even a total esquillectomy.* The object of clearance at this stage is to display the area clearly and to remove everything which interferes with complete exploration of the injury and with drainage. In more than two-thirds of cases the operation ultimately leaves the ends of the shaft in contact, thinned down but forming an almost continuous trunk, without reducing the total length of the bone.

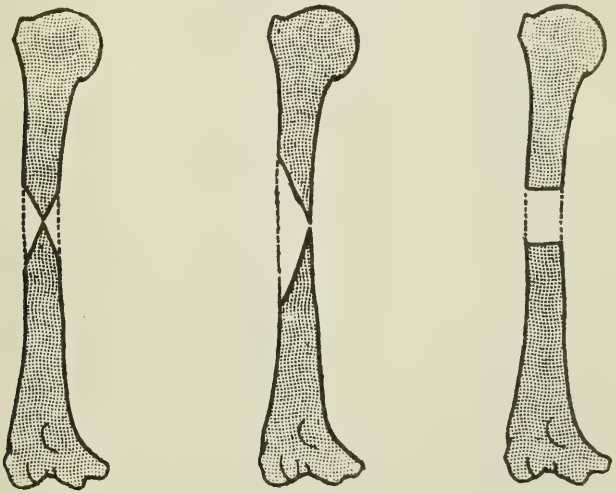
In large-splintered fractures it is indeed sufficient to remove the principal fragment obscuring the medullary cavity. After the operation the continuity of the bone is hardly interrupted. Anyone doubting this has only to think of the classical description of the "butterfly wing" fracture, which is equivalent to this type; removal of the lateral fragments leaves the extremities of the shaft intact, and meeting at the point of impact of the missile.

In fractures with one large and short splinter, it is enough to remove this, detached as it is and wedged

between the ends of the shaft, and still adherent to muscles, together with any smaller fragments of it which are already dead; when the clearance is complete, the shaft has lost nothing in length, but is only deeply notched.

In fact, *in at least two-thirds of the cases, free esquillectomy reduces the thickness and not the length of the bone.*

This being the case, it is illogical to hesitate at esquillectomy; the anatomical arrangement of the ends of



FIGS. 18, 19, and 20.—Diagram showing what is left by esquillectomy adapted to the lesions in different types of fracture. Compare figs. 1, 2, 3, and 4.

the shaft is such that consolidation is possible even after an esquillectomy almost regardless of the periosteum, and cannot fail after an entirely sub-periosteal operation.

There remains the case of *shattering into small splinters*: if the shaft is shattered in its entire circumference, clearance is necessarily total, since scarcely any of the splinters are adherent. In theory, there is some fear of a false joint, but if great care is exercised in preserving scraps of periosteum, if the very

natural desire to remove more or less adherent fragments by a sharp twist or violent pull is resisted, if any remaining periosteum is carefully removed from free splinters with a rugine (such splinters being found on the outskirts of the fracture), a kind of periosteal sheath remains—lacerated, no doubt, but sufficient in its length to ensure the formation of a regular callus.

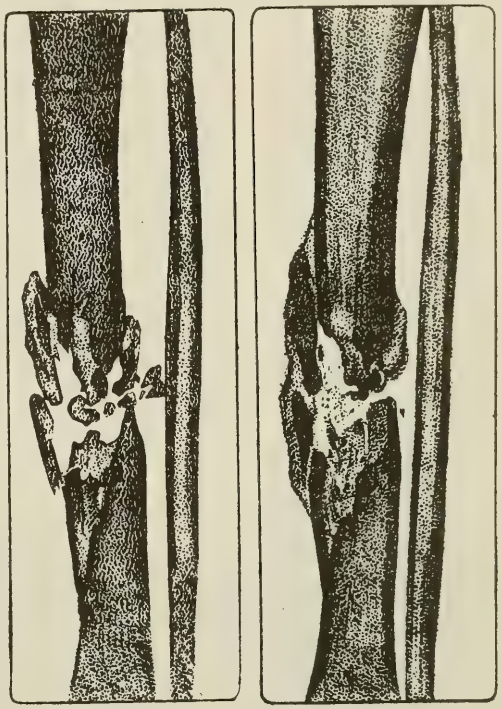
Here the process is decidedly longer than in the preceding cases, but it is equally sure and reliable; the callus which results is equally solid, particularly if no attempt is made entirely to prevent shortening by applying too powerful an extension.

Although in the former cases (the large, long-splintered type and that with one large short splinter) I have seen firm union occur sometimes in 30 days in the forearm, in 35 in the humerus, in 42 in the leg, and in 45 in the thigh, 2 or 3 months elapse when there is extensive shattering: it begins slowly towards the 35th day by the formation of a fibrous, slightly elastic and flexible mass which gradually hardens, generally on one side at first, and eventually becomes a solid and regular callus. Often, moreover, the missile not having struck the shaft squarely, the blow was more or less glancing, and, after removal of small splinters, a projecting piece of the shaft remains.

All possible criticism of removal of fragments is negatived by the arguments I have reiterated here.

But esquillectomy has another very great advantage to which attention has never been drawn, and which is of great interest: *it is the only sure means we possess of moulding the callus at will* in the right direction. When numbers of splinters are left on the borders of the area there is a temptation to use them as supporting arches for ossification. If they happen to remain, bone-formation begins around them—that is to say, to some extent along a different axis from that of the bone itself; the callus, from the way in which it is formed, will be shapeless, irregular, and

redundant; sometimes it will enclose fragments of muscle, and I have twice seen pseudarthrosis produced in this way in the centre of a partially ossified mass. If there is any infection, the marrow will die and disappear, and no bone-forming tissue will be there to fill the central cavity; thenceforward an infected cavity will persist in the centre of the bone, the cure of which will be difficult if not impossible. If, on the other hand, all fragments of bone forced out and displaced by the injury are removed, and one side only of the shaft is allowed to remain, the periosteum will be grouped by muscular pressure round the grooved bar remaining, and the callus will form along this in the shape of a regular solid column, with no gap or infected cavity: bone-formation is, as it were, guided, and the callus thus produced will give infinitely more security for the future than one built around diseased, dead, or displaced fragments.



FIGS. 21 and 22.—These two radiographs, taken at three months' interval, show well how fragments left in place cause an outward bulging of the periosteum, and how, owing to this, a central cavity is formed within the callus. Compare fig. 10.

Decidedly, instead of hesitating at wide preventive

esquillectomy, the surgeon should regard it as the ideal operation for fractures, since, while entirely protecting the bone-forming tissues from damage by infection, it ensures the formation of a healthy callus in a regular way—a callus enclosing no undesirable foreign body, nor threatening any subsequent formation of fistulæ.

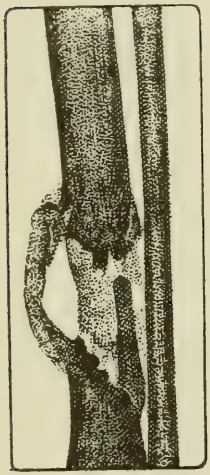


FIG. 23.—Bridge of periosteal callus formed along an adherent fragment in the lower third of the tibia; the splinter, which occasioned a fistula, had to be removed; the protruding callus ulcerated the skin of the leg, and had to be removed later in order to bring about healing.

**B. Secondary operative disinfection of clinically infected fractures: Esquillectomy and drainage: total sub-periosteal esquillectomy.**

The reasons for regarding wide sub-periosteal esquillectomy as the preventive operation *par excellence*, should, for stronger reasons, bring it to be regarded as the only form of intervention ensuring the disinfection of recently infected fractures. It is a typical drainage operation, since it completely exposes the injured area, and abolishes everything which could facilitate the development of infection, *i.e.* the closed cavity, unhealthy débris, and tissue of diminished vitality

Practically, it rules out all serious sepsis, rapidly removes less serious infection which is tending to become chronic, and quickly abolishes all infections which cannot develop in the presence of air: it thus assures the regular formation of a healthy, and in no way pathological, callus. This callus is not an outer shell enclosing an empty central cavity, but a compact, connecting column, in one piece, having nothing in common with the misshapen callus produced by a diseased periosteum round an infected medullary cavity.

No other operation can fulfil these purposes; if any fragments of diminished vitality, around which infection may, and often does, develop, are left in a fracture, the operation is not one to be relied on to give

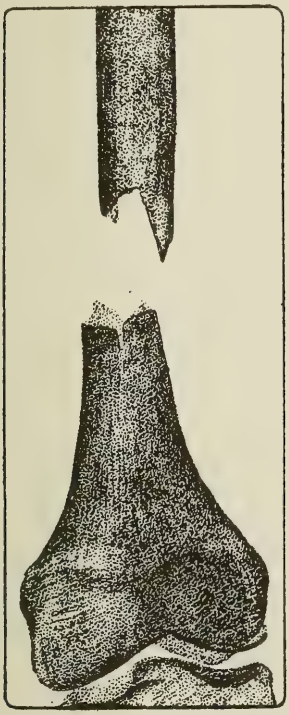


FIG. 24.—Copy of a radiograph made after secondary supplementary esquillectomy on the thirteenth day for fracture of the thigh. A large adherent splinter left in place was removed, as were two pieces of shell, one of which was in the medullary canal. The suppuration stopped at once without the use of an antiseptic.

FIG. 25.—Sketch showing the callus obtained in sixty days. Union had occurred forty-eight days after the operation. The patient could walk on the sixty-second day.

an invariable and sure result.

It is not a matter of *mere drainage of the soft parts*. The pathological physiology of infections forbids any thought of that.

Partial and prudent esquillectomy, *i.e.* a hesitating

and incomplete operation, is fatal in leaving the principal infected area untouched: it deliberately avoids the root of the trouble, and permits neither a thorough search for fragments of metal and clothing nor an exploration of the medullary canal, which is absolutely necessary. It limits itself to a little tentative draining, and is often carried no further than this; sooner or later amputation is necessary in cases which this method has proved incapable of curing. It is easily judged to-day by its results; it has peopled our towns with men who have lost limbs and has filled the hospitals with unfortunate men whose wounds have been suppurating for months, almost for years, still possessing incurable sinuses in spite of all treatment.

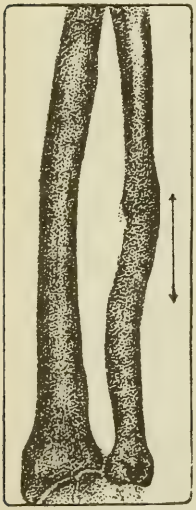


FIG. 26.—Radiograph of a callus in the ulna, six months after total secondary esquillectomy. Compare figs. 95, 96, 97, 98, which illustrate the same case.

The anatomical and pathological conditions of an infected fracture are such that any intervention which does not establish drainage of the medullary canal and removal of all débris about to undergo necrosis is a bad operation. Theoretically this is so; it is also true in practice.

Blind and partial operations should therefore be dismissed.

On the other hand, wide esquillectomy which allows of thorough exploration of the wound, removes necrosed, infected, or infectable tissue débris, and, having thus displayed the wound well, leaves in it only elements necessary for repair, and at once and invariably ensures automatic disinfection and drainage; it does for the infected shaft-fracture what sub-periosteal resection will do for an epiphyseal fracture.

It should, therefore, be employed at once and systematically in all fractures whose course is not clinically aseptic.

What has been said of periosteal bone-formation after sub-periosteal esquillectomy, and the X-ray photographs which will be found in the book, will suffice, I believe, to show that the method does not tend to produce pseudarthrosis.

Briefly, *wide sub-periosteal esquillectomy is the only logical operation in harmony with present-day anatomico-pathological theories on the development of septic fractures in warfare.*

*No other permits complete exploration of the region concerned, and treatment of the injuries caused by the missile after thorough exposure of the wounds to the air. Owing to the exploration, prevention of infection, and drainage which it includes, this method alone consistently achieves continued asepsis of the fracture. Thus it ensures the normal production of a healthy callus from the bone-forming tissues which it has preserved in the wound. These, restored by the rugine to their position in relation to the shaft, will develop a regular osseous column in line with the shaft, without the empty central cavity which is so favourable a seat for chronic infections.*

**C. General indications for the operation.**

1. As a preventive of infection.—Sub-periosteal esquillectomy should be carried out as early and promptly as possible *in all fractures caused by fragments of shell, bomb, or torpedo, or by bullets with accompanying explosive effects.* In all these cases no clinical sign of infection should be waited for before operating. As in all penetrating wounds of the abdomen or joints, an exploratory transosseous operation is absolutely necessary. Apart from tracheotomy or the ligature of a large vessel, no class of case calls more urgently for intervention than this: in the ambulance, the exploration of limb fractures should be carried out

immediately; if it is a matter of choosing between several cases, some of which will be obliged to wait, *fractures should receive attention first.*

In the event of a rush, the surgeon at the front is strictly bound to deal with the greater number, and with those whose life he is most certain of saving, and whose condition he is best able to improve. He is under a definite obligation to operate on fractures rather than abdominal cases should they arrive simultaneously, unless he is certain of being able to deal with all within a limited time: twenty esquillectomies are worth more than ten laparotomies, the definite gain from the humane point of view being greater.

It goes without saying that these rules are irrelevant to periods of relative quietness, when there is time for everything.

*But what should be done in the case of shock?*

Many cases of fracture, particularly those of the thigh, are in a condition of severe shock. Should the operation be postponed until the next day? Are these cases in too critical a condition for a general anæsthetic and a necessarily rather long operation? A careful esquillectomy requires half to three-quarters of an hour: is this not too much for men who are faint and chilled?

Yet complications may be imminent. A case exhibiting severe shock is sometimes threatened by serious infection, and will not survive unless an immediate operation is performed.

Theoretically the question appears insoluble; practically, it is a matter of judgment. A case exhibiting severe shock will not be transferred direct from the stretcher to the operating-table; the first step is to treat the shock. The patient is placed in bed in the horizontal position with the head low, and is warmed, and ·01 grm. morphine is immediately given: morphine acts marvellously in the majority of cases, apparently counteracting the peripheral vaso-

constriction. By a reverse process a similar effect may be attempted, by endeavouring to induce contraction of the abdominal vessels in order to restore the quantity of blood contained in them to the general circulation : this justifies the use of emetine (·05 to ·1 grm), or of pituitrine : this method is superior to the injection of quantities of saline, which perhaps often has an effect opposite to that desired. On the other hand, small doses (150–200 grm.) of very warm saline containing adrenalin, injected intravenously, and repeated every two hours, give excellent results.

After five or six hours the operation is performed. It should not be delayed longer ; shock which resists the above treatment has a permanent cause in the region of the wound which must be removed at once. Some of these operation cases will die, but experience shows that in these fatal cases, shock persists until death, and nothing would have been gained by waiting. Others recover without difficulty.

Is it possible to distinguish between these cases ?

Clinically not, but Sencert has shown that the height of the blood-pressure gives definite information : there is a minimum pressure, and should the patient's fall lower than this, there is every likelihood that he will succumb rapidly. All cases which Sencert has seen, whose blood-pressure before the operation, measured by Vaquès' apparatus, was below 10, died ; the rest recovered. Apart from this excellent procedure, there is no definite anti-operative indication.

In the absence of shock, should all fractures be treated by *immediate* operation ? Yes, all *fractures by fragments of shell, bomb, or torpedo, or by bullet with accompanying explosive effects.*

In fractures by shrapnel balls, shown by X-rays to be such, a few hours' delay is theoretically justified, if time is plentiful, to decide whether an operation shall be performed. Infection is less constant in these cases than in fractures by a shell-fragment. Arrange-

ments, however, should be made for the case being watched closely, for there are a number of these fractures whose course is identical with that of the worst shell-fragment fractures (those in which the bullet, originally spherical, but more or less deformed on impact, has carried in fragments of clothing with it). If, therefore, there is a large influx of wounded, there should be no delay; the fracture, though perhaps benign, is treated like the rest, rather than risk death from sepsis, or an amputation, in a case which originally appeared the least serious of all.

In practice, I think it better to make no distinction between fractures by shrapnel balls and others; the fundamental rule of prevention holds here as elsewhere, and it is better to perform the operation in nine cases not requiring it than to lose a single life by refraining from it. It is, moreover, certain that the nine operations will not prove to have been useless.

In bullet fractures with small skin wounds, but larger than the punctiform type, clinical signs should be awaited, and treatment limited to immobilisation. Infection is not usually fatal; it is often benign, and the patient can be evacuated forthwith. But if the wound of exit exceeds one inch in breadth, immediate preventive intervention is required, since serious infection is usual in this case.

2. As an operation for drainage.—Sub-periosteal esquillectomy should be done at once in all clinically infected fractures, and in any seen after twenty-four hours or later. It should be practised even if there has been an earlier intervention, should the case present signs of increasing infection, or if the wound is suppurating after an interval of several days. This is frequently seen at base hospitals. In fact, the majority of cases sent back from the front are suppurating to some extent, in spite of various antiseptic dressings. These wounds appear clean, but they are never aseptic; the infection is slight, but it

is nevertheless an infection, and this should not be so. Suppuration after five, six, or eight days, and particularly after a longer time than this, is indisputable proof that the original cleaning was incomplete, and that there are still fragments of bone and gangrenous tissue to be removed which have been left in the wound, involuntarily or not: to speak plainly, the operations in these cases have been incomplete.

In fourteen shaft fractures arriving in fifteen days during an offensive, I found under X-rays splinters undergoing necrosis in fourteen cases, and in all the cases I operated to remove them. In eleven cases careful and methodical sub-periosteal esquillectomy, ethyl chloride being used as an anæsthetic, was sufficient to arrest suppuration and *enable the injury to take a clinically aseptic course.*

This result could have been obtained at the outset. In five cases adherent splinters were removed in which were engaged fragments of clothing whose spontaneous elimination appeared impossible. In three cases successive operations were required for the draining of abscesses, and an aseptic condition of the wound was only obtained at the end of a fortnight.

It will perhaps be said that this secondary cleaning was, to say the least, useless, and that the majority of the cases would have recovered equally well had I left them quiet and well immobilised.

This is not my opinion: I believe it to be very bad for a fractured bone and the surrounding muscles to be in prolonged contact with pus. The production of leucocytes and the proteolytic phenomena which lead to the elimination of dead tissue, result in irritation of the periosteum, in sclerosis of the muscles, and in perceptible interference with recovery of function in the wounded limb. It is a mistake to regard suppuration, even of a benign nature, of war-wounds as an almost normal phenomenon; it will be asked with

astonishment in the near future how it has been possible for so important a factor in anatomical and functional recovery to be misunderstood.

To return to my cases. I do not doubt that in a few of them suppuration would slowly have eliminated some of the splinters which I removed, and union would eventually have taken place without a second operation; but I am certain that the callus produced in this way would have been inflamed, bulky, and painful. Now this result seems to me far from the ideal which should be aimed at in war surgery at the present day. There are calluses and calluses; only *aseptic* callus-formation should be sought after, and it is certainly being content with little to be satisfied with having obtained union of diseased bones with osteomyelitic extremities.

*A pathological callus is a bad callus, and a reproach to the surgeon.* Any fracture whose fragments are united by a section of inflamed bone, produced by diseased, swollen, and hypertrophied periosteum, encircling a cavity of varying size which contains free or fixed dead splinters, is a fracture viciously united after having been badly treated at the original operation. Similarly with sinuses. Up till now only *anatomically defective* callus has been considered vicious; that is, the cases in which the normal axis of the limb has not been restored, or articular surfaces below the fracture have been left in abnormal relation. Up to the present *pathologically vicious* callus has been very rife; every day numerous examples are seen of diseases of the callus, not formerly known to exist. and all who have had to operate on these are, I believe, already convinced that pathological callus produced by an incomplete operation at the outset is more difficult to deal with than the anatomically vicious form produced by incompetent post-operative supervision: orthopædic surgery is more sure of its results than the surgery of the results of infection.

But it will be objected that every callus is not necessarily inflamed or fistulous. Decidedly not, but chronic osteomyelitis is not the only danger that threatens a septic fracture. *Pseudarthroses* are produced by *inflammatory sterilisation* of the ends of the bone ; *dense calluses* also occur, with marginal osteitis, uniting fractures in useless limbs riddled with incisions, with sclerosed and rigid muscles and tense, shining, purplish skin. For some of these men, condemned to pain and crutches, an early amputation would often have been better than the preservation of such a limb as this.

It is for this reason that, in spite of the opinion of certain surgeons, when a fracture suppurates after an originally insufficient intervention, the surgeon should not simply wait for the suppuration to cease : *a further attempt should be made to render the injury aseptic and so to ensure the subsequent regular progress of the case.* A more or less early secondary esquillectomy will quickly succeed in rendering the wound aseptic and arrest the formation of pus : if the operator is determined to do it strictly sub-periosteally, as he easily can, owing to thickening of the periosteum, he will have the satisfaction of seeing union occur without complications after a normal lapse of time. For this a far-reaching operation is necessary—and sufficient—one which achieves at once what others expect suppuration to perform, at the expense of considerable injury to bone and surrounding soft parts—*i.e.* the removal of tissue undergoing, or about to undergo, necrosis, contused surrounding skin, crushed and lacerated muscles, splinters torn away and displaced : *it should leave nothing to be eliminated spontaneously.* The esquillectomy itself should remove not only free splinters embedded in muscles or imprisoned far up the medullary canal, *but also, and principally, adherent splinters*, already diseased, which bar the way to the medullary canal, and are found with their surfaces

rough and disintegrated. Some surgeons recommend drawing subtle distinctions between splinters by their colour and resonance when struck by an instrument. There is no object in attempting such a differentiation, or in leaving in the wound useless structures of diminished vitality, which will for a long time encourage suppuration, and ultimately die. If the periosteum is carefully preserved, everything is retained in the wound necessary for the formation of an ample quantity of healthy bone; there is no risk of pseudarthrosis, and the column of bone thus formed will always be almost exactly of the same length as the original shaft, much more nearly so than in the case of a fracture in which the splinters have been retained.

FIG. 27. — Infected fracture of the humerus, three days old.

FIG. 28.—Condition of the fracture three days after total subperiosteal esquillectomy.

In every case after such intervention, and without the use of antiseptics, the wound invariably becomes aseptic in a short time (usually five or six days). If the suppuration lasts longer, the reason undoubtedly is that a splinter in a corner of the wound has been forgotten. A verification by X-rays should be carried out without delay, and any fragments remaining should be removed.

Thenceforward there need be no further fear of purulent cavities, muscular sclerosis, or neighbouring phlebitis. The callus about to form will be healthy, built up in a normal length of time by vigorous osteogenetic tissue, whose functional activity is unimpaired by any infection.

*Counter-indications.*—But although secondary sub-periosteal esquillectomy is indicated in recent fractures not yet united (*i.e.* less than a month old), it is nevertheless dangerous in old suppurating fractures where new bone is in contact with old and diseased bone. In this case, wide clearance, which must traverse a barrier of newly formed bone, causes violent injury in a closed space, opens up large areas for absorption, and regularly causes suddenly acute sepsis, always very serious, sometimes fatal, and likely to demand immediate amputation.

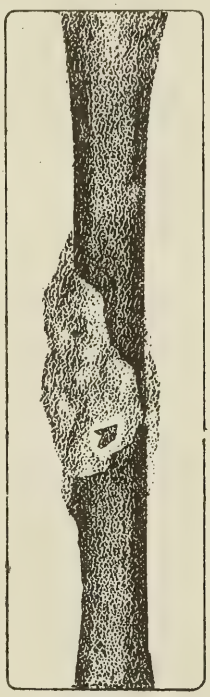


FIG. 29.—Same case as in figs. 27 and 28. Radiograph made at the end of five weeks; there was very little pus-formation. The wound not being completely closed, I was able to pass forceps in and remove the small free sequestrum seen here.

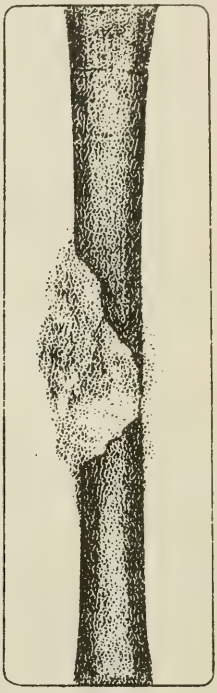


FIG. 30.—Condition at the end of sixty days. The muscles are all preserved intact. It is impossible, on seeing the play of the limb, to guess that the patient has had a serious fracture.

Esquillectomy, in such injuries which can be investigated only with difficulty, is certain to leave behind it recesses and infected fissures: only subperiosteal resection of the shaft will expose all the diseased tissue and allow of its being dressed.

*For this reason, esquillectomy should never be attempted after consolidation has commenced.* The surgeon should limit himself to draining abscesses and removing obvious sequestra with forceps; spontaneous elimination of the rest must be relied on, and no attempt made to get the sinuses to close until the proliferation of firm bone, enclosing the sequestra, has definitely localised the area of infection.

If the general indications given here are followed, the treatment of fractures will be found to be simplified enormously. They will run an aseptic course, without tracks of pus, abscesses far removed from the injury, secondary hæmorrhages, or elimination of sequestra. They will consolidate without forming sinuses, and, when the callus is formed, cure will be final, without complications, and without the reappearance of infection.

3. Special Indications: Particular Cases: the choice between Esquillectomy and Amputation. —So far I have only discussed splintered fractures evidently justifying an operation for restoring continuity and function; but should not the extent of the injury sometimes demand an amputation?

In other terms, what are the anatomico-pathological limits of esquillectomy?

*In the upper limb* I know of none, apart from irreparable injuries to blood-vessels and nerves. For anyone who can make the necessary incisions and can use a rugine suitably, there is no bone injury that can in itself necessitate amputation. If there is any prospect of preserving normal function in the fingers, a conservative operation may always be performed, apart from removing the humerus in its whole extent,

or a large extent of bone in the forearm ; even entire removal of the humerus is permissible, and I have personally resorted to it in one case. Certainly periosteal regeneration of the bone removed cannot always be expected, but an artificial structure will replace it, and no amputation stump can compare with a functional hand at the end of a flail-arm. But if muscular destruction is considerable, and if important tendons have been destroyed over a wide extent (*e.g.* severance of the flexors or extensors of the fingers), preservation is pointless and amputation should be preferred.

Similarly if, together with extensive injuries to bone and muscle, the three nerves of the hand have been severed in the arm, it is unreasonable to hope for regeneration of the median, radial, and ulnar, when their point of injury is in the region of a serious fracture. Under these conditions, esquillectomy should be rejected, and the radical operation preferred.

An isolated arterial or venous lesion does not in itself contra-indicate esquillectomy : the vessel may simply be tied in a suitable place, and the operation on the bone be performed as usual.

*In the lower limb* the factors concerned are different. The function of the lower limb being to support the weight of the body in an upright position and in walking, the solidity of the limb takes precedence of all other considerations ; the only conservative surgery is that which preserves function, and it is not preserving function to retain a thigh or leg which is not rigid. Esquillectomy is therefore not justified, unless followed by a regeneration of bone sufficient to ensure solidity. According to very wide investigation, apart from some exceptional cases of very extensive regeneration, I believe that any initial clearance which leaves a gap 5 to 6 in. long in a bone essential to the upright position (femur, or tibia), is a doubtful operation to which amputation is preferable. Of course esquil-

lectomy may be carried out in the first instance, amputation being postponed for some days, in order that the latter may be carried out more regularly, at leisure, and with more discrimination under aseptic conditions. It would also be possible, after extensive removal of bone, to attempt a bone-graft: early subperiosteal esquillectomy having reduced the injured area to an aseptic condition, the graft could be placed early in aseptic surroundings and have some chance of success. It would be equally possible to attempt a bone-graft from a fresh corpse. This is a reasonable alternative, for theoretically it is correct to hope for a good result; but this is not the place for discussing these methods, and they cannot affect what I have said above—there are injuries of the femur which should be recognised at once as requiring amputation.

In later stages attempts at preservation may be carried further, regeneration of bone being more abundant. But nothing should be exaggerated, and the above figures are almost a maximum.

Briefly, in present-day surgery, a fracture of the femur or tibia involving loss of more than 6 inches of the bone should be amputated at once.

Similarly, certain extensive muscular injuries combined with a serious fracture may demand amputation.

On the other hand, a vascular lesion should not, as a rule, affect the treatment which the fracture appears to require. After ligature of the femoral, esquillectomy in the thigh is still an excellent operation, provided that the shock be not too great.

Nervous lesions (severance of the sciatic) should not modify the treatment of the fracture.

The main factors governing the advisability of esquillectomy may be summarised as follows:

*In the upper limb, esquillectomy should be done, whatever the extent of the injury to the bone, whenever (apart from complete cure) satisfactory recovery of function in the hand is assured.*

*In the lower limb, it should be rejected whenever recovery of the function of support cannot be expected.*

**D. Technique of sub-periosteal esquillectomy.**

This is a delicate, minute, and deliberate operation, which demands time, patience, and, if possible, an exact previous knowledge of the topography of the fracture. There is every advantage in not undertaking it until after X-ray examination or complete X-ray photography from both the lateral and anterior aspects, permitting accurate estimation of the number and position of the missiles, and appreciation of the rough shape of large splinters and the general arrangement of the injured region.

1. Anæsthesia.—Esquillectomy requires complete anæsthesia ; in no case should the surgeon be content with a local anæsthetic. The operation may, in fact, be a long one, and its extent is sometimes much greater than was at first anticipated. I habitually use ethyl chloride on an open mask, which allows of an operation lasting three-quarters of an hour to an hour with the advantage of immediate anæsthesia and rapid and uncomplicated recovery of consciousness, two much-appreciated features in a very busy hospital. For the lower limb, spinal anæsthesia by novocaine and adrenalin is extremely convenient.

2. Disinfection of the soft parts.—It is of great importance to begin the operation by carefully disinfecting the wounds of entry and exit. The contused cutaneous edges of each orifice should be excised ; then, the wound having been enlarged anatomically in the way described, the fascial sheath, which is usually little lacerated, and tensely stretched over the structures beneath it, is incised to the extent necessary to display the whole of the injured region. Then, without introducing the fingers in a clumsy attempt at removing fragments, two retractors are placed in the wound, permitting inspection of its superficial features, intermuscular intervals, tendons, and so on. Any

contused and lacerated muscle or other soft tissue is removed with great care by means of forceps, and the smallest fragments of clothing or soil are looked for; in fact, the whole wound is cleaned as patiently and minutely as possible.

At the exit wound even greater care is required; the muscles are often filled with osseous débris and minute splinters of bone, which should be removed with the utmost care. Gentle separation of fasciæ and muscles will reveal scraps of clothing so situated that they might well have escaped observation. Ecchymotic patches, which often undergo necrosis, are usually found in contused muscles, at some distance from the main injury; the exploration of the soft parts must therefore be carried to the extreme limits of the injured region. All suspected patches should be widely excised; even parts should be removed which appear simply lowered in vitality, and which the surgeon might feel inclined to leave untouched. These strict measures are necessary in order to avoid the disagreeable surprise, some days later, of finding large patches of necrosis in a wound which had been supposed healthy.

The entry and exit wounds, when suitably enlarged, will serve for the esquillectomy if they are conveniently situated. When this is not so, if, for instance, both are on the same aspect of the limb, or if they are too far apart, and far from the fracture, as is the case when the track of the projectile is very oblique, or if they are situated in a dangerous area, they should merely be cleaned and freed of injured tissue as above described, and the bone operation should be performed through a fresh incision made in a suitable position.

Metallic fragments are removed at once, if necessary, by means of fresh incisions. The bistoury and forceps should then be used along the track in the opposite direction to that taken by the missile until

the fracture is reached; here fragments of clothing and dead splinters will usually be found.

3. TREATMENT OF THE BONE.—Near the bone, particularly on the side of the exit wound, numerous splinters will be found. Previous to digital exploration or blind search with instruments, two retractors are introduced, and the first step is to remove with forceps all absolutely free splinters scattered in the wound. They are generally completely detached, no adherent fragments of periosteum retaining them; their tendency is to work out spontaneously, and their removal is an easy matter. This is carried on towards the shaft itself. From this point onwards *all interference must be strictly sub-periosteal, and the slightest attachments of periosteum must be preserved.* For this purpose each adherent splinter is gripped by means of small forceps * or a volsella, and the rugine is used to scrape the periosteum carefully away from it, not to liberate the splinter, but in order to leave the osteogenetic tissue covering it, in the wound. The nearer to the region of adherent splinters the greater should be the care exercised. The very natural temptation to tear away what still holds by a sharp pull or violent twisting, must be resisted, as only the fibrous tissue is separated in this way, the bone-forming layer remaining adherent to the bone; only patient and methodical use of the rugine will preserve the whole of this, together with the non-osteogenetic external periosteum. For this purpose the cutting rugine of Ollier which I have described in Part I (p. 30) is absolutely necessary; those who do not use it, but employ other instruments (the rugines of Farabeuf and Legouest), cannot be aware of the difference between the two instruments.

I have already stated what adherent splinters should be removed; all that are found to be loose, all whose

* Heitz-Boyer has recently had forceps made by Collin which seem to me perfect for this purpose, so good is their grip.

reduced vitality will later be further lowered even by a slight infection, and finally all which block the way to the medullary canal, and prevent exploration of it, should be removed. It is for these that the patient use of a very sharp rugine is absolutely necessary: no fragment of periosteum should be left on the bone removed, and when the operation is finished, in place of the original shaft there should be a definite cylinder of periosteum, remaining there like a mould of the original, and the outline of the future bone.

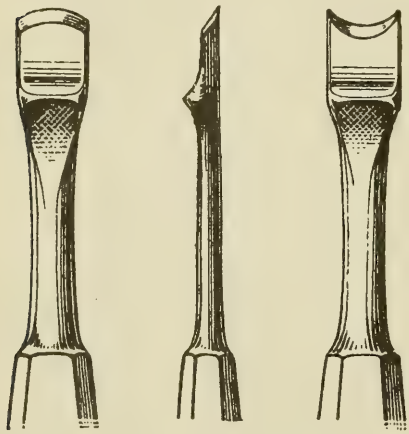


FIG. 31.—Ollier's cutting rugines with which the periosteum, including its deep layer, may be completely detached.

Often, in detaching visible adherent splinters, a large and still adherent fragment will be disturbed whose existence had not been suspected; this the surgeon may hesitate to remove on account of its length. Its removal is advisable, since shreds of material are likely to be adherent to its deep surface: at one time I left such fragments, now I remove them, having sometimes seen them become infected and inflamed. Moreover, this removal is not a disadvantage, large splinters never being circumferential; it in no way endangers the consolidation of the bone if the periosteum is left in place, and the procedure has the advantage of displaying the whole area affected by the fracture and levelling recesses where infection might develop; for these reasons it should be carried out without hesitation. In other cases, on the borders

of the injured region, where the bone is healthy, two splinters are sometimes found, 1½ to 2 inches in length, obliquely situated outside the line of the shaft, as it were like lateral splints. They may appear perfectly healthy, but if they are left they frequently become infected, and produce excrescences, contributing to the malformation of the callus. I no longer make a practice of retaining these.

It is not easy to state theoretically how far esquillectomy should be carried. It varies with different injuries; the essential point is that the medullary canal should be explored thoroughly, that no necrosing débris should remain there, so that the marrow may be scraped away as far as the injury extends and no fragment of bone remain imprisoned.

Clearance should be more complete the longer the operation is delayed, in the first place because aseptic development is assured from the outset if the exploration has omitted nothing, further because secondarily the question of free drainage is pre-eminent, since the periosteum is more easily detached and more productive.

In brief, at the outset, wide clearance is sufficient; later, it is often better to carry out total clearance.

When large splinters are present, this sometimes results in leaving nothing in the wound but the two pointed extremities of the shaft, which are in contact.

Where there is a large tangential splinter still adherent, a longitudinal groove is left in which bone is rapidly re-formed.

On the other hand, in fractures involving one large short fragment, the gap left will merely consist of a deep notch.

Where there are many small splinters, a gap 1¼ to 1¾ inches in length will often remain.

Finally, in transverse fractures, esquillectomy is replaced by sub-periosteal resection of the crushed and contused ends of the shaft, in order to produce a drainage gap about ¾ inch in width.

*The essential point is in every case to perform everything slavishly with the rugine*, and to preserve all the periosteum that can be found anywhere.

In the immense majority of cases, the surgeon, if he is patient and careful, will succeed in leaving a more or less complete cylinder of periosteum, or a periosteal sheath unbroken in its long axis, and this will suffice for the formation, in a normal length of time, of a good and healthy callus.

This done, and the medullary canal being well exposed, it is cleaned for about half an inch with a curette. The operator will always be surprised at what is brought to light in this way, as, for instance, fine splinters, broken scales of bone, and foreign bodies (projectiles and fragments of clothing) particularly in the regions of the epiphyses. This *curetting*, which should be performed without violence or excess, is absolutely necessary.

When the wound has been freed from splinters and the extent and variety of the injuries made manifest, it is sometimes necessary to trim the pointed extremities of the injured ends of the shaft by means of cutting forceps. In certain regions, wherever there is much cancellous tissue, and close to epiphyses particularly (notably above the elbow and in the supra-malleolar region), I have frequently trimmed the ends of the shaft with a saw : half an inch of the bone is lost in this way, but absolutely healthy bone is reached, and rapid consolidation, and good sound callus, amply compensate for this slight sacrifice in regions which are dangerous owing to the proximity of joints. There is, however, a disadvantage in this method when a secondary esquillectomy is concerned : the end of the shaft often detaches itself after some weeks in the form of an annular sequestrum, as a consequence of death of the marrow and detachment of the periosteum. This is sequestration by vascular necrosis.

Care should be taken throughout to secure hemo-

stasis: small vessels in the muscles should be ligatured, and at the end of the operation the wound should be clean and dry, without clots or oozing.

The fracture should also form, as it were, the base of the wound proper (*i.e.* injury to skin and muscles); the latter should not stretch over and mask it, but take the form of two truncated cones meeting at their apices, that point corresponding with the centre of the medullary canal.

4. Dressings.—*The necessity of loose plugging, and the disadvantages of primary or secondary suture.* A loose mass of aseptic gauze is placed in the wound formed as above, as also in all incisions which have been required for the removal of foreign bodies or for any other reason. Drainage tubes serve no purpose and amount merely to useless foreign bodies: I never employ them.

Plugging of the periosteal cavity is necessary; the gauze plays the part of an irritant which others expect infection to perform; it activates the periosteum, and I do not know whether ossification would be so satisfactory without it. It also prevents approximation of the oppositing layers of periosteum, preserving the shape of the interfragmentary space in which bone-formation will take place. For the same reasons I regard infrequent dressing as advisable, and do not recommend either immediate or secondary attempts at closure of the wound. Apart from the risks of infection caused by immediately closing the wound, I consider that the method should be rejected because it prevents reactivation of the periosteum which is effected by plugging.* I have on several occasions seen consolidation occur in twenty-four hours after the third or fourth dressing, as if the irritant effect of

* Ollier taught that everything should not be sacrificed to the desire for a rapid cure by first intention. Aseptic secondary closure appeared preferable to him from the point of view of bone-formation. Everything that I have seen up till now leads me to believe that he was right.

the dressing had suddenly released a new activity in a still perfectly soft callus.

After plugging, the limb is heavily padded and carefully immobilised by one of the methods which will be suggested later for each type of fracture. The dressing is left in place for a period of eight to fifteen days, sometimes longer; in fact, after such an operation as has been described, asepsis of the wound is almost invariable, and this allows of everything being left in place, absolute immobility being ensured; when the gauze is removed, a healthy surface is found, oozing blood, and at the bottom of the wound, a perfect granulating membrane formed from the layer of periosteum. The dressing is repeated with aseptic gauze, gently introduced into the wound, and is allowed to remain in place there for a further ten days. After three or four dressings, the onset of consolidation may be expected.

This process, following on well-performed subperiosteal esquillectomy giving normal results, occupies from thirty to sixty days according to the region involved. The bone is often solid before healing of the superficial wound is complete. But the course taken by this aseptic wound is so simple that I see no great advantage in closing it by sutures.

Little modification is required by a septic condition of the wound: if the soft parts are seriously infected, swollen, and œdematous, I prefer a dressing of moist gauze, soaked in concentrated saline (10% to 14%), to a dry dressing. This should be left in place for two or three days; it produces profuse suppuration, the pus being of a greenish-yellow colour. When it is removed, whitish patches will be found scattered over the granulations; this organic débris is removed with a swab or forceps, and the wound is well dried and treated by heliotherapy, or by a stream of hot air. Under the action of the sun, the wound becomes glazed, then bright red, and oozes a

considerable amount of lymph, as I mentioned in connection with wounds after articular resection (see Part I, p. 29), submitted to the action of the sun. With hot air the effects are the same, but slightly less pronounced. A second moist saline dressing is kept applied for a further two days, after which it is generally possible to resort finally to aseptic gauze dressings, aeration, heliotherapy, and hot air.

I shall not discuss further the advantages of systematically employing physical agents in the restorative treatment of wounds: I emphasised them sufficiently in Part I. I merely repeat that aeration, heliotherapy, and the hot-air douche are to me a fundamental feature in the treatment of all gunshot wounds, and that up to the present we have no more effective means than the sun for reducing the severity of a wound and accelerating its spontaneous healing.

Fig. 32.—Annular sequestrum from the end of the shaft of the femur, removed after two and a half months, in a case in which esquillectomy had been performed at the front.

The formation of the callus should always be watched by means of X-rays: several radiographs are necessary for verification, particularly after comparatively late secondary operations: in these cases the edges of the wound are sometimes seen to have become œdematous, and some thick pus appears, particularly if the ends of the shaft have been trimmed with a saw; a radiograph of the fracture at this period reveals a small notch on the edge of the shaft; this is a small sequestrum which has just become detached, and its removal by forceps is sufficient to clear up this slight complication, which could have been anticipated if the progress of the fracture had been watched by X-rays, and the successive stages in the formation of

a callus followed by this means. If the treatment is carried out in this way, none of the complications by infection, of which so many surgeons speak, will occur: far-reaching tracks of pus will not develop, neither will associated arthritis, lymphangitis, nor secondary hæmorrhage. Progress will be simple from first to last, and cure will be effected without a trace of the troublesome sequelæ which for years afflict the unfortunate men whose wounds their surgeons have not desired or dared to disinfect early and completely.

It is often surprising, particularly after a total secondary esquillectomy, to note the rapidity with which the callus forms. I mentioned on p. 326 certain statistics which will undoubtedly appear exaggerated to some. They are, however, absolutely exact.

But it should be added that a callus formed in so short a time is not very hard, and that immobilisation should be continued for a long period after consolidation has been ascertained. Recently in a case in which I performed a secondary esquillectomy for a sub-trochanteric fracture, in which the limb could be raised on the forty-second day, the callus became bent between the seventieth and eightieth days, the extension having been removed on the sixty-second day, and the patient having left his bed and walked at about the sixty-fifth. I applied extension on the ninety-third day, and succeeded by the use of weights (7 to 8 kilos) in correcting it almost completely.

There should therefore be considerable delay before free use of the limb is allowed: sixty days at least for the upper limb and 120 for the lower limb. I shall resume this subject in connection with particular fractures.

### II. The Reduction of Gunshot Fractures

Reduction in these cases is not, so to speak, a distinct operation, the result of co-ordinated movements such as are carried out for simple fracture of the radius, or for Dupuytren's fracture, for instance. The multiplicity of fragments and splinters, the incalculable element introduced by muscular laceration and the irregularity of the area affected, render this impossible; and when there is definite over-riding, as in fractures of the upper part of the femur and humerus, the muscular force to be overcome is such that the most vigorous movements at the time cannot reduce them. After such wide clearance as has been described, the matter is different: reduction is almost always practically realised when the operation is over, or, at least, it is very much facilitated; frequently it consists simply in immobilising the limb in the physiologically correct position; in any case, prolonged extension always gives the result desired.

In theory, three methods of reduction may be employed:

Reduction by open operation (fixation by plating, etc.),

Rapid reduction by manipulation,

Slow reduction by continued extension.

1. Reduction by open operation.—The invariably septic condition of all gunshot wounds absolutely forbids reduction by this method as practised by Lambotte and Lane in the simple fractures of civil practice; attempts should not be made to restore large fragments and splinters to their original position, supporting the whole by metallic apparatus (bronze wire, clasps, or plates). Certain surgeons may have been tempted to do this at the beginning of the war, on examining a fresh wound during the first few hours, before any signs had appeared of the serious infection which was developing there. The rapid

appearance of dangerous septic conditions has absolutely and finally barred the renewal of such attempts : in some cases sepsis was fatal, others had to be amputated, in others widespread necrosis of bone occurred. I have seen shocking examples of the latter at medical boards.

On the other hand, it is quite conceivable that after free preventive esquillectomy, this method of reduction might appear tempting : it is so simple to use a plate or wire to unite the two contiguous ends of the shaft, when the injured region, its surfaces made plain, cleared of all infecting débris and all its splinters, is clean and uncomplicated.

I am persuaded that this could be attempted with frequent, if not constant, success on the single condition of keeping the wound widely open and dressing the osseous region itself without obstacle. Although never having actually done this, with my experience of the progress of fractures after free esquillectomy, I shall not hesitate to attempt it under favourable conditions in regard to supervision and apparatus.

But in practice, this reduction with immediate reunion of the bones by osteosynthesis is not advisable and should not be made a routine procedure : war surgery should before all things be safe surgery ; every case should be enabled as soon as possible to be evacuated without danger ; a minimum of supervision should be required, for it is possible that the patient cannot be closely observed ; an operation case, during the hours following the operation, may be finally separated from the surgeon and sent on a long journey. Artificial union of bone, even under the aseptic conditions which I admitted in theory above, may prove, if the operation is not absolutely complete (which is always possible), to be the origin of serious complications which must not be risked in the case of wounded men : it may only be attempted when the operation takes place in the earliest stages, and when constant

and prolonged supervision is assured for the patient. In any other circumstances, it should not be performed on any account.

It also possesses the disadvantage of perpetuating the shortening when a reduction of the interfragmentary space has occurred, assuming that periosteal proliferation succeeds in filling the gap. Finally, it is unnecessary: *free esquillectomy, such as should be practised, simplifies the region of fracture to such an extent, that reduction itself is realised by it:* it is enough to immobilise in good position to ensure automatic reduction, or an easy realisation of it with the help of continuous extension.

Briefly, *sub-periosteal esquillectomy is the best operative method of initiating a good reduction.*

2. Rapid and forcible reduction.—This consists in restoring the correct position of the fragments by a single effort by means of powerful traction and suitable manipulations. This is very easy in certain regions, when the fracture has been widely cleared; it is, on the contrary, very difficult, sometimes impossible, whenever the fragments have been left in place and some are laterally displaced, as is usually the case. Marked displacement is the result of strong muscular action which can only be overcome with difficulty under an anæsthetic, and much less without it.

Immediate reduction may be attempted in two ways, either by means of manual or instrumental means followed by the immediate application of immobilisation apparatus, or by immobilising apparatus with adjustable springs which apply rapid extension and correct the displacement at once.

In the former case (taking as an example a fractured thigh), an attempt is made, under an anæsthetic, by traction in a definite direction, to bring end to end the two fragments of the shaft; when this is effected, they are fixed in position by a large immobilising

plaster casing applied while the pull is being exerted, and only removed after consolidation has occurred.

In the latter, Delbet's apparatus is used for a fractured thigh. This appliance, which will be described later, gives very powerful extension, and reduces serious displacements in a few seconds.

But sudden reduction is often painful; frequently it is scarcely bearable unless it merely attempts to place the lower fragment in line with the upper, pending immobilisation of the limb (as in supination of the hand in fractures of the forearm); further, it does not always give accurate results, as is proved by X-rays, and in the main there is every advantage in the slower method by continuous extension. This is so true that Alquier, the surgeon who has perhaps had the most experience of Delbet's apparatus, has completely given up rapid reduction.

Immediate reduction is only demanded by one circumstance; the improvised application of a temporary apparatus for transport when a rapid evacuation is expected, for it is important to immobilise after as perfect a reduction as possible. But absolute confidence should not be placed in the results apparently obtained, and when the transference of the patient has been effected, the original apparatus should not be retained permanently unless it is shown by X-rays that the desired reduction has been obtained. This is unusual, and as a rule it is better to resort to progressive reduction by continued extension, a slow and gentle, but sure, method.

3. GRADUAL REDUCTION.—This is the preferable method: the ceaseless action of continued extension has a marvellous reducing action, giving no pain and abolishing muscular contraction, which obliges the bones to resume their original positions, restores structures to their normal relations, and thus enormously favours drainage and repair.

It is advisable in any region, and can only be wholly dispensed with in the forearm.

It can be produced in different ways:

(*a*) *Continuous extension by Weights.*—The usual procedure is an extension by weights fixed to a stirrup applied to the limb by adhesive plaster, or by an adjustable screw pulling on the stirrup itself. The traction is exerted on the lower fragment through these bands and the soft parts. It is of advantage to apply the stirrup, when possible, to the whole length of the limb as far as the groin or axilla, wherever the fracture may be situated, but unfortunately the existence of wounds is often an obstacle to this. The strips employed should preferably be adhesive,* applied directly to the shaved skin; they should be applied over as wide an area and as high up the limb (*i.e.* leg, thigh, arm, or forearm) as possible, in order that the circular or overlapping strips that fasten parallel ones to the skin may not slip down enough to cut into the skin just above the joint below, which is extremely painful, particularly at the knee.

The strips to form the stirrup are put on parallel to the limb, and made fast by others wound spirally round it. The tension is distributed in this way, which is preferable to winding only two or three turns, which rapidly become painful. On the other hand, they should approach as near as possible to the region of the fracture. If possible, there should not be a

* Failing leucoplast, and in place of the old diachylon (lead) plaster, different adhesive substances may be used, liquefied by warming in a water-bath, and applied to the strips of bandage. Amongst the very numerous formulæ which exist, the following has been recommended:

| | |
|---|---|
| Rosin (colophane) . . . | 50 grammes |
| 90 per cent. alcohol . . . | 50 ,, |
| Venice turpentine . . . | 5 ,, |
| Benzine . . . . . | 25 ,, |

This is spread over the limb with a brush, and extension bands of calico are laid down upon the skin. I have had no experience of this method.

joint interposed between the point of application of the force and the bone upon which it is to act. It is wrong to exert traction on the leg in order to pull on the femur, since this permanently upsets the knee, causing terrible difficulties in the future. Traction should be exerted in a definite direction suited to the particular case : it should always be exerted in a line with the upper fragment, which is differently acted upon by the muscles, according to the height of the fracture : thus, for instance, the lower fragment of the humerus or femur should be abducted in fractures situated slightly above the middle of the shaft.

There is one further remark to make on the subject of continuous extension by weights : permanent traction is more efficacious when exerted on parts of limbs whose muscles are relaxed. The relaxed position in the upper limb is that of semi-flexion of the elbow and pronation ; in the lower limb, semi-flexion at the ankle, knee, and hip. These positions should be utilised, since continuous extension is more easily tolerated and more efficacious when these physiological considerations have been taken into account. This is of great importance in fractures of the thigh.

*Continuous extension by weights, based on these theories, is the best method of reducing fractures*, and should be employed for preference. It has also the inestimable advantage over all other methods of being easily applicable anywhere, and by very simple means, which in war surgery is an essential point.

Continuous extension by weights may also be established by means of a *laced boot* or *plaster gaiter*, on the plantar surface of which a small ring is fixed for traction. But a plaster gaiter is often painful, and such means have the further disadvantage, if they are employed for fractures of the thigh, as is usually the case, of exerting the pull from too great a distance, stretching the knee which is already distended by slight hydrarthrosis.

(*b*) *Extension by a transfixion Nail or metallic Loop.*—A more precise, or at least more direct, method, is that of extension by means of a nail, the latter transfixing either the femoral condyles or the os calcis. Many surgeons are quite reasonably not attracted by the idea of transfixing a bone. But in spite of its disadvantages, if the method gives better results than others, there is no reason for hesitation in adopting it. Those who have employed it say that the method is painless and safe, and brings about reduction of the most serious displacements. I have had occasion to examine several cases which had been treated in this way for fractures of the thigh. The results were very mediocre: there were shortenings of from 2½ to 3 inches, and X-rays showed considerable overriding which had not been corrected at all.

On the other hand, if the fracture is carefully cleared by free esquillectomy, reduction is easily obtained by continuous extension on ordinary lines, always provided that it is applied in the right direction. During twenty months of war, I have not yet seen a fracture which I could not reduce satisfactorily by the usual methods. But it is obvious that all these methods will fail if the line of traction does not correspond with that of the upper fragment.

I see, therefore, no necessity for extension by means of a nail; it uselessly complicates the treatment, and should never be employed.

Is this also true of Finochietto's modification which Chutro has recently introduced into France for fractures of the thigh?

This method consists in passing a strip of metal over the upper surface of the os calcis in front of the tendo Achillis. A metal stirrup, through which traction is exerted, is fixed to this strip (figs. 33, 34, 35). It may be left in place for some weeks without inconvenience.

Finochietto's stirrup is a decided improvement on

extension by means of a nail; it is a refinement of what some surgeons have done by fixing a simple loop of wire in the same position; theoretically, the same objection applies to it as to other methods of traction from a distance—it pulls on the leg and thus tends to produce disturbance at the knee. Chutro and Heitz-Boyer assert that the extension is perfect, and produces no such undesirable effect. This should therefore be a procedure to hold in reserve, and to utilise if it is actually proved that after powerful traction the knee is not dislocated, for a fixed joint is preferable to a flail one.

Lastly, the extending force may be exerted by *elastic traction*. This is only used exceptionally; apart from the appliance for fractures of the thigh (to be described later), invented and used by Sencert, I know of no example of it.

The weights may be replaced by an adjustable screw apparatus which easily gives very powerful continuous extension.

(*c*) *Extension by sliding or spring Appliances*.—There is an entirely different type of appliance in which continuous extension is produced by springs, and by shafts sliding one over the other, adjusted by some kind of mechanism.

The typical appliance of this type is that of Pierre Delbet, in which extension is obtained by means of a flanged spring which forces apart two shafts which slide in a tube and are each connected with and act on the limb, the one above, and the other below, the fracture: above on the axilla, for instance, and below on the forearm, which is kept flexed at right angles by means of a sling.

Many excellent appliances of different kinds have been invented on this ingenious and practical model. Usually they consist of two plaster collars of varying length, incorporated with two hollow shafts sliding one over the other and enclosing a spring which tends

continually to separate the two resisting points, that is, the two plaster collars; the latter by means of the sliding concentric shafts and the pressure thus con-

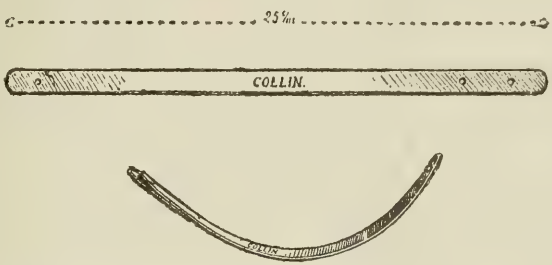



FIG. 33.—Metallic strip and its guide (Pedro Chutro).

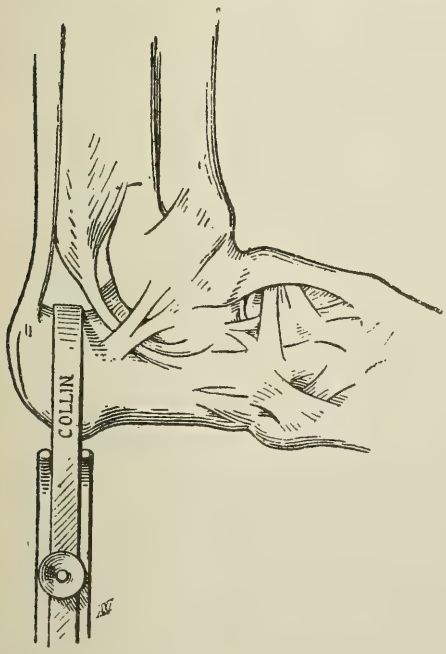



FIG. 34.—Position of the metal strip in relation to bone and tendons (Pedro Chutro).

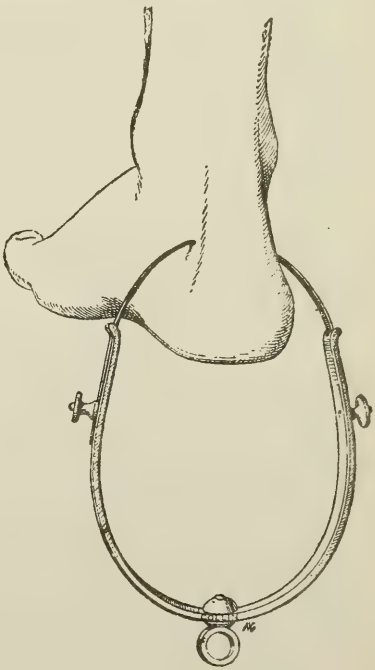


FIG. 35.—The apparatus in place (Pedro Chutro).

tinuously applied to the lower collar submit the limb to permanent extension.

It will be seen that a large number of appliances

exist for producing continuous extension in fractures. All can give and have given good results, for what is of more importance than the variety of appliance used is the sound application of the fundamental principle on which all are based ; the technical method is a matter of convenience, and its importance is secondary.

As it is very difficult to choose between the numerous procedures recommended, I shall discuss in connection with each fracture the appliances which I use, without even alluding to those of which I have no experience ; this does not mean that they are faulty, or should be rejected.

Lastly, *after free esquillectomy permitting of infrequent dressing, the question of apparatus is much simplified*, since the progress is clinically aseptic, and it is usually necessary only to dress the wound at long intervals.

### III. The Immobilisation of Fractures

All fractures should be immobilised for a long period. It is too often forgotten that immobilisation is at the root of all treatment directed against infection : without it, the injured area is constantly subject to further trauma, further infection of the wound is continually being produced, great increase in the virulence of the infection being the result. For this reason it may be said that immobilisation is a prime necessity of disinfective treatment ; it is also indispensable for avoiding pain, and for maintaining reduction, thus favouring the formation of the callus.

Theoretically the best method of immobilising a fracture consists in uniting the fragments, either by wiring, a plate (Lambotte), or by a clamp of the type devised by Dujarier.

This *operative fixation* of the fracture, however, is rarely, and should not be generally, employed. At-

tempted indiscriminately, at the beginning of the war, by surgeons to whom the constant infection of gunshot fractures was unknown, it brought disaster and was condemned. It might, however, perhaps be excellent in certain cases, after careful operative disinfection and free sub-periosteal esquillectomy, if the object were merely to produce provisional union of the bones, and the wound were kept open. But it should not be supposed that this primary osteosynthesis after sub-periosteal esquillectomy is applicable under all conditions and to all cases. Useful and beneficial if operative disinfection has been complete, it becomes dangerous if some overlooked débris threatens to provoke the development of acute osteitis. It should also only be attempted in cases operated on early, by a trained surgeon who is certain of being able to look after the case for a long period.

Further, all cases in the above categories do not justify it. It might be indicated in all aseptic fractures in which, after sub-periosteal esquillectomy, only two pointed extremities of the shaft remain, meeting at their apex ; it would then be easy and useful to unite the two fragments by a Lambotte plate. But when, on the other hand, clearance has given rise to extensive loss of bone, and a fairly large interfragmentary space, osteosynthesis is not advisable, since it would cause too great a shortening, whereas a periosteal callus, filling the interfragmentary space, will unite the two extremities of the bone with very trivial diminution in length.

When it is added that it is not without danger in infected fractures, it will be agreed that it is only advisable in exceptional instances.

Lastly, operative fixation cannot suffice in itself ; it must always be reinforced by an immobilisation appliance. This consideration decidedly reduces its value.

Initial fixation by metal is therefore likely to re-

main an unusual method * at the front, and recourse should be had usually to the indirect methods of immobilisation. The latter are numerous, many are excellent, but their use is not always satisfactory, because the fundamental rules of good immobilisation are not understood, because sometimes the conviction of its necessity is not sufficiently strong, and lastly, because there is sometimes an unjustified conviction of its riskiness. In reality, it should be stated as a principle that such a thing as too rigorously or too completely immobilised a fracture cannot exist. Immobilisation after esquillectomy should be the principal care of every surgeon.

**A. The principles governing immobilisation.**

1. THE PRINCIPLES OF BONNET.—Fixation has for a long time been a difficult problem to all who have not paid the closest attention to the early disinfection of fractures; they have continually to fight suppuration, and hence are compelled to dress the wounds at least once daily, they have to watch closely the spread of infection, to make complicated and repeated arrangements for drainage, to carry out secondary esquillectomies, and to irrigate freely with antiseptics in order to sweep out necrosed organic débris. Suppuration prevents the accurate adjustment of any fixation appliance; dressing is difficult and painful; continuous friction between the opposed fractured surfaces results in numerous small local injuries which promote infection, thereby interfering with disinfection and repair.

Attempts were made to abolish these disadvan-

* While correcting the proofs of this book, I received two cases in which the large splinters had been surrounded by a wire suture. After three months there was no consolidation, and the wire gave rise to a permanent sinus. I removed the wire, and consolidation occurred soon afterwards, but the fragments were necrosed and had to be removed. After eight months, these patients have not yet recovered. There was therefore no advantage in the method.

tages by reintroducing the interrupted plaster casing, a large number of which were badly conceived and violated the fundamental principles of fixation. By continually evolving new appliances, some very ingenious solutions have been found in spite of very real difficulties, and some of these innovations will live in surgical therapeutics, but this was *approaching the problem from the wrong side :* the only method of simplifying dressings, and of rendering them painless and harmless, is to disinfect the area of the fracture at the outset, and thereby avoid suppuration in it. It then becomes much easier to arrange for an ideal immobilisation, and above all, nothing then interferes with its maintenance.

*The only ideal immobilisation is that which fixes the extremities of the bone exactly in a definite position, without possibility of displacement in the region of the fracture, and without causing pain to the patient.*

That this may be so, to follow the classical and often misunderstood principles of A. Bonnet, *the articulations above and below the fracture must be immobilised*, that is to say, the whole limb must be immobilised.

This fixation, which must be maintained until consolidation has occurred, must be as rigorous at the beginning as at the end—at the beginning, to avoid pain and contribute by rest to the disappearance of infection ; at the end, when the callus is about to form, in order that the new bone may assume a correct shape and that there may be no deformity of the limb.

But immobilisation thus understood has the disadvantage, according to its own principles, of fixing the neighbouring joints. This is of little importance if it is not maintained too long ; if, on the other hand it be prolonged, muscles atrophy, joints stiffen and when at length the bones have united, the functions of the limb have been impaired as a direct result of the

immobilisation. The result is therefore far from being perfect.

As a matter of fact, when he was studying immobilisation and formulated the rules which the entire world has adopted, Bonnet had only articular pathology in view, and did not consider fractures. It is certain that, to immobilise a joint, the two epiphyses forming it must be fixed. Now these cannot be maintained in complete repose unless all movement is suppressed in the epiphysis of the other end of the bone, the slightest displacement of which reacts on the opposite end of the lever (*i.e.* of the shaft). This amounts to stating that the whole joint must be immobilised, and no other solution but that of A. Bonnet is possible. But in shaft fractures the case is different, and for these the problem may be studied differently, an attempt being made to give the joints free play.

2. New principles for the immobilisation of fractures.—As a matter of fact, if the circumstances are pictured, it becomes evident that, to immobilise a fracture, there is no need to fix the joints above and below it: it is enough to fix the fragments concerned in the desired position by means of a metal shaft taking purchase against the projections of the corresponding epiphyses, or on the soft parts surrounding them, that is, above and below the joints situated below and above the seat of injury respectively. The theoretical appliance which realises this, is as it were a form of external prosthesis, buttressed against the epiphyseal projections, closely comparable, in fact, to the internal prosthesis represented by a Lambotte plate. After this the neighbouring joints are free, and can move, if not normally, at least enough to preserve their flexibility. Pierre Delbet succeeded in reducing this to practical form, evolving appliances which gave extension and at the same time only involved the actual segment of the limb concerned,

leaving the neighbouring joints relatively at liberty while buttressing close to them, either against some lateral support (the edge of the axilla, for instance), of which use is made in the case of spring appliances, or on fixed bony points of support utilised by means of a plaster casing. Descriptions of these appliances will be given later. For the present it is sufficient to mention an ingenious practical realisation of the principles stated above.

3. THE PRINCIPLE OF SLING SUSPENSION.—This solution of the fixation problem which certain American surgeons have given, is entirely different and even more simple : it is really a paradoxical solution, since it appears to suppress immobilisation itself, or at least immobilising appliances, but it is nevertheless excellent. It consists in placing the limb in a kind of hammock, suspended in the air and kept in position by weights, and applying continuous extension ; the opposing force is exerted by the weight of the elevated limb. Fixation is due to the fact that movement of the injured region is only possible *in toto*, and cannot occur within the region. This form is excellent ; it possesses the advantage of preventing all friction due to local muscular contraction, suspension abolishing all resistance and allowing only of displacement *in toto* of the fractured region which itself is fixed by traction and counter-extension.

In fact, fixation in space is realised by preventing transmission of the forces of movement, the principle utilised being that of suspension from a universal joint.

**B. Means of securing immobilisation.**—There are three possible methods of immobilising, which innumerable appliances have been designed to realise. All can be employed, but each is indicated by particular conditions. It is necessary to understand their management thoroughly, not only their instrumental, but their therapeutic use.

It is this that I shall endeavour to explain in studying the different types of fixation according to the principles on which they are based.

Later I shall indicate which should be chosen in the case of any given fracture.

1. Fixation according to the classical rules of A. Bonnet.—This is the classical form, which should be thoroughly understood, for it remains the fundamental method, and the method for cases of urgency; ignorance of it is inexcusable. *During an influx of cases, it is the only possible method; during evacuation it is the only advisable method; in a war of movement, no other can be employed.*

There are numerous ways of arranging it—that is, of immobilising the fracture by immobilising the whole limb, but they are very far from being of equal value.

(*a*) *Metal splints.*—Whether made of iron wire, iron gauze, or aluminium, these are convenient, quickly applied, and, except for the thigh, furnish an excellent means of temporary fixation: they represent material always ready at hand and quickly applied, they do not alter in shape or become foul, and they can be sterilised by flaming at each dressing. Delorme's models in aluminium are very light, and do not interfere with examination by X-rays.

In spite of such qualities, these splints are never efficient appliances; they immobilise only indifferently, they mould themselves to the contours of the limb and not of the bones, and consequently cannot really maintain a reduction; as soon as the padding becomes deranged or the bandages loosen, they no longer immobilise at all. Lastly, they do not effect the continuous extension which lies at the root of the treatment of almost all fractures.

*Trough splints are not suitable apparatus for treatment; they are only temporary and provisional appliances, and should not even be used as makeshifts for a*

*journey if there is time enough to make better arrangements.*

(*b*) *Reed-blind material.*—This is a war invention. It was first used in the form of a sheath for rapid temporary fixation (Pauchet), then in the form of splints (Eynard), and finally as plaster-splints (Eynard-Santy).

Three to five thicknesses of ordinary reed-blind material, 3 inches in width, are superposed, each surface being padded with a layer of cotton-wool, very useful long splints being obtained in this way.

For fixation of the *lower limb*, three may be used: one, about a yard in length, is placed posteriorly, beneath the leg, bent up at right angles to follow the outline of the heel: two others, 30 inches long, are placed laterally, one on each side of the leg. The whole thing is held together by the application of tarlatan bandages.

When the thigh and hip are concerned, it is well to use thicker splints, consisting of four or five thicknesses of material. The posterior one, bent up at the heel, is from 52 to 60 inches in length, reaching as high as the waist and taking a firm purchase there. An external lateral splint passes from the heel to the iliac crest, and on the internal aspect is a third one, its upper extremity heavily padded; at the genito-crural fold this takes its purchase from the ischio-pubic ramus. Securely fixed by a large spica bandage, these splints can be made in a few minutes to form an appliance in which the patient suffers no pain and which offers strong resistance to movement.

The use of blind-material is equally simple and practical in the *upper limb*.

If the forearm, elbow, or lower extremity of the arm is to be immobilised, two splints 2 inches wide and consisting of two or three thicknesses are sufficient. After flexing the elbow at right angles and pronating the forearm, a postero-external splint is

first fitted to the extensor aspect of the limb, after being broken at the elbow. It should be a yard in length, passing upwards as far as the posterior border of the axilla, and downwards flush with the ends of the fingers.

A second shorter (18 in.) slip is placed along the flexor aspect after being suitably bent.

The blind splint is a good appliance in early stages, but it possesses the disadvantage of being fixed by the dressing itself, and must be removed whenever the wound is to be exposed; it is also permeable by secretions. This has led to the use of plastered blind-material, which is equally manageable and at the same time more rigid and resistant.

This consists of a form of casing made up of three or four thicknesses of material; this casing is directly surrounded by two thicknesses of stiffened tarlatan, kept in place by a few stitches; by this means the splint, dipped into liquid plaster, is satisfactorily impregnated, and retains sufficient plaster to set well. The appliance is completed by plaster bands connecting the splints and forming a certain number of rings at intervals. After this, free access to the wound, and supervision of the injured limb in its entire length, are easy matters.

These excellent appliances give good fixation and are easily handled.

(c) *Plaster appliances.*—Plaster is the most widely applicable and practical method of immobilising fractures: it meets all requirements, and is so convenient and manageable that nothing can take its place. Certain appliances and arrangements, may, in a given case, be more comfortable and assure a better result, but if there were to be only one procedure for treating fractures, plaster would certainly be chosen. Happily, however, this is not the case, and selection is possible. This does not alter the fact that in present-day surgery, and war-surgery in particular, plaster appliances,

in spite of certain disadvantages, remain as the basis of fracture treatment. Some surgeons criticise them severely; they do not, however, understand their use, for it is a definite art. A good plaster should not give pain, cause ulceration, or grip too tightly, and should immobilise thoroughly. It is all a matter of care.

*Method of making a Plaster casing.*—There are two types of plaster appliance, troughs and circular bandages. In principle, the troughs are removable and the circular bandages are not. In practice, windows of varying size are left in the circular form, and the different parts are connected by plaster or metal bands; in this way the wound is left exposed as desired so completely and so well that circular plasters are now the appliances that really allow of convenient dressing, troughs no longer being employed except for wounds which are very infrequently dressed.

In any case, a plaster must be large, and moulded to the projections of the limb. By "large" it is meant that it should immobilise the two adjacent joints according to the principles of Bonnet.

The appliance should not be directly applied to the skin, even if the latter has been shaved and greased. It is better to interpose a thin layer of flannel, gauze, or a few turns of bandage without reversing. It is useless to pad any bony projections except the patella; it is better to model the plaster round them with the thumb, and not on them. Ulceration is avoided in this way. The best isolating material in the case of a trough is ordinary paper, rolled about the dressing and the limb when the plaster casing is about to be applied.

*The plaster* which should be used is plaster of Paris (modelling plaster). If it is at all old or stale its properties may be restored by heating for a few minutes. A definite quantity (about 4 kilos) is required for a plaster for the lower limb. It is often well to mix it in two successive portions in two neighbouring

basins if a complicated appliance in several pieces is to be made.

*Dressed tarlatan* (tarlatane gommée) is the vehicle of the plaster, and is employed in the form of bandages or strips. *The bandages*, which can easily be made in the hospital, should be 5 to 10 yards long and 4 to 6 inches broad. They are prepared for use by being rolled up after passage through a basin full of dry plaster, or by rolling them with one hand, while the flat of the other spreads the plaster over the tarlatan, which lies flat on the table. According to Calot, who has written a practical book on plaster appliances, full of useful advice, the outcome of long experience, about 2 oz. of plaster are required for each yard of tarlatan 6 inches wide, 10 ounces for 5 yards of bandages. When about to be used, the plaster bandage is plunged into a basin half full of slightly warm water (not saline). It is ready for use when air-bubbles cease rising, *i.e.* in two to three minutes. A fresh bandage should therefore be placed in the basin after one to two minutes, if several are to be used. Excess of water should be squeezed out before the bandage is applied. The application should begin at the extremity of the limb, passing upward towards the trunk, in order to avoid initial constriction of the veins.

The plaster usually sets ten minutes after its application was begun.

The turns should be regular and without reverses ; the left hand methodically arranges and smooths the bandage, while the right applies it by simply unrolling it without pulling or tightening : it is easy to predict how the apparatus will be tolerated by watching how it is put on.

I repeat what I have already said on the subject of bony projections ; the thumb should be carried round them so as to model the bandage closely to their contours in order that they may support and fix the

casing, and therefore not be ulcerated by it. If desired, a circular plaster may be cut open down the long axis of the limb, giving two halves easily removed and reapplied.

*Trough splints* are made with tarlatan slips consisting of eight to twelve layers. They should be cut longer than appears necessary; they can easily be cut down later to the desired dimensions. In width they should not exceed half the circumference of the limb; there is a tendency to make them too wide, covering part of the anterior surface of the leg or forearm, and causing a certain amount of difficulty in their removal. Adaptation to the flexures of the limb is ensured by cutting notches that allow one part to ride over the other when the strip is bent.

*The liquid plaster for the splint* should be made in a large basin with cold water, without salt. According to the classical formula, more plaster than water should be added, five parts of plaster to four of water. There is an advantage, however, in thickening the paste a little further, by the addition of more plaster than is prescribed, and, like Calot, I use for choice five parts of plaster to three of water (by volume). An excellent but slower method consists in sifting the plaster through the tarlatan, which is stretched over a basin, until the powder floats on the surface of the paste like small pieces of ice in water.

When the paste is ready it should be used at once without further dilution or thickening. It is better to start afresh than to attempt any alteration in its consistency: any attempt at improving it almost always makes a failure of the appliance.

Whatever the type of appliance used, it should not cover the wound; gaps are cut in the splints, or openings are made. To recognise the position of wounds and to know where to cut out an opening, it is enough to mark the place on the dressing by placing a few drops of tincture of iodine on the gauze immediately

previous to applying the plaster ; a violet stain on the appliance will soon mark the position of the wound to be uncovered.

These windows are made with a bistoury or a shoemaker's knife about half an hour after the plaster has set ; they should expose the skin widely round the wound, and their edges should be covered with gauze or bound with strapping.

If the wound or wounds are very extensive, and if the fracture is suppurating profusely, recourse may be had to interrupted splints. I shall discuss their use later (see p. 377), but confine myself for the present to describing their construction.

The principle is to apply two close-fitting circular plaster bandages, one above and one below the region of the fracture, and to unite them by metallic loops, or by plaster loops reinforced by wood, wire, or tow, the ends of which are incorporated with the plaster. In constructing them, the fundamental principles of fixation have often been misunderstood—thus metallic loops passing from the shoulder to the forearm have been recommended for fractures of the humerus. These gross therapeutic errors are no longer made at the present time, and the interrupted appliances now made rigidly fix the two bony segments to be immobilised.

The circular plaster bandage should extend sufficiently far along the limb in each direction to render the joints above and below the fracture immobile.

Briefly, interrupted appliances which originally left too much of the limb exposed tend at the present time to be nothing more than circular appliances with bracketed interruptions. This development was inevitable ; the laws of fixation demanded it.

The circular plaster bandages are applied according to the usual rules, and two or three metal loops, prepared beforehand of the required dimensions and

bent in the right place, are fixed on each of them with a plaster bandage.

The bandage may be carried from one circular part of the splint to the other by covering the metallic loop with it, or, on the other hand, the metal may be left exposed.

The same thing may be done with any more or less rigid kind of support, or more simply still, plaster strips may be constructed from a fairly long piece of bandage. For this purpose it is enough to unite the two circular portions by a few longitudinal strips of plastered bandage, fairly long and not too tightly stretched, round the ends of which a few turns are made with another bandage to cover and secure them; a series of soft connecting loops is thus obtained, which may be pulled outwards from the limb by the fingers and kept in that position until the plaster dries.

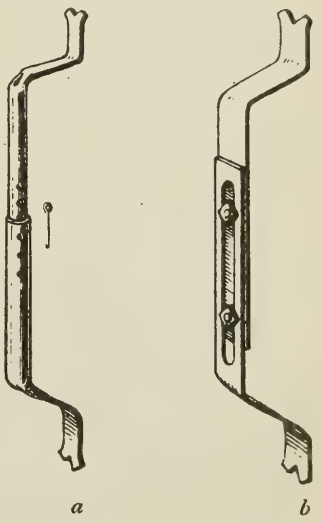



FIG. 36.—Metal loops with (*a*) a spring, (*b*) nuts.

These appliances are interesting, but as a matter of fact, however well made they may be, they possess great disadvantages: very soon the limb becomes loose within the casing enclosing it; it begins to have too free play, and fixation is less rigorous; overriding occurs, and some degree of angulation between the two ends of the shaft is produced, so that the actual therapeutic and orthopædic result obtained is mediocre.

Hence the idea of *plaster casings with extensible metallic brackets, or brackets consisting of tubes sliding*

*one within the other, i.e. continuous extension plaster appliances.* These are actually only copies of Pierre Delbet's appliances. But these modifications are convenient, and their use should become general.

To construct them it is enough to replace the ordinary flat metal loops by metal slats sliding one over the other which can be fixed by means of a wing nut, or by hollow rods of different diameters sliding one within the other, or again by shafts with a spring resembling those of Delbet's apparatus. By exerting traction on the end of the limb, it is possible, if necessary, to produce the extension judged to be useful. Perforations and a pin allow the tubes to be

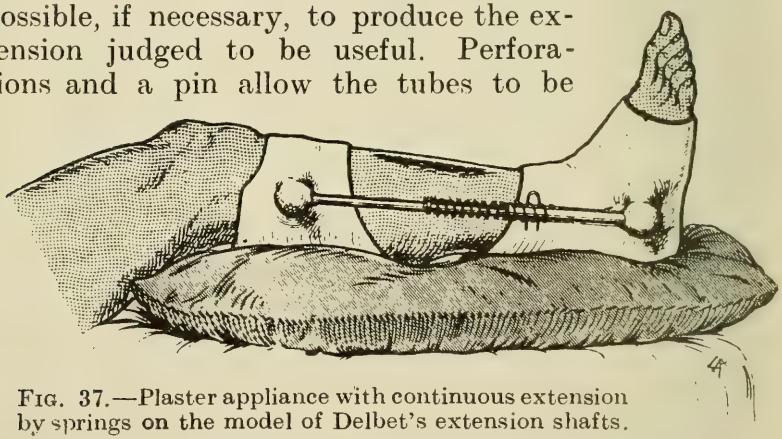


FIG. 37.—Plaster appliance with continuous extension by springs on the model of Delbet's extension shafts.

fixed in any position. Excellent and compact appliances are constructed in this way for the leg (see fig. 37); they are easily improvised everywhere and are of great service.

These continuous extension plasters are far preferable to simple plaster appliances, which usually reduce displacements and deviations unsatisfactorily.

*Advantages and disadvantages of, and indications for, Plaster appliances.*—The great advantage of the plaster appliance is that it is easily made, and reduces pain by producing admirable fixation, diminishes infection, and makes for recovery.

It is criticised on account of the trouble in dressing

and supervising these wounds which it causes, and its frequent tendency to produce compression and ulceration.

All this is true, but it is all a matter of supervision, and no fracture appliance exists which does not demand a great deal of attention.

Plaster should be employed whenever rigorous fixation is required for a patient who is to be left a comparative degree of liberty; for this reason plaster is the ideal transport appliance; lack of time sometimes prevents its use, but it should never be forgotten that for evacuation nothing can take its place. *The best plaster for this purpose is the classical plaster trough well adjusted;* a postero-external scapulo-metacarpal splint for the arm; a dorsal humero-metacarpal splint for the forearm; a dorsal pelvi-pedal splint for the thigh; and a posterior cruro-pedal trough for the leg.

On the other hand, the plaster trough does not allow of continuous extension, and it is for this reason, in a general way, that it is not advisable except at the beginning and the end of the treatment.

Circular plaster appliances are scarcely suitable except in the third stage, when reduction by extension has already been produced, and union is on the point of commencement or completion.

On the other hand, continuous extension plasters are excellent appliances for the active period of treatment, if it may so be termed.

Interrupted appliances are not often advisable: there has been much misuse of these appliances which so many surgeons suppose they have invented, whereas they had been abandoned for thirty years, and have been recently reintroduced by Gourdet. The very great ingenuity required and displayed in their construction has been one of the factors of their success. They are now being given up, which is only right; as a means of fixation they have given indifferent results, and they have often served to conceal serious errors

in treatment. They immobilise badly, and soon allow insidious slippings and secondary over-riding, and should therefore be used only for short periods in particular cases, and in definite circumstances—when, for instance, an extensive wound requires to be widely exposed, in a patient who is able to get about.

In fact, if the fracture suppurates, it is not an interrupted plaster appliance that is required, but an operation; if the wound is large and the patient condemned to bed for any reason, he will do far better with a suspension apparatus; if the wound is not suppurating and the progress of the case is normal, infrequent dressings allow of a plaster trough being used.

The practice of immediate or secondary sub-periosteal esquillectomy, the aseptic development of the wounds, and the rapid formation of a periosteal callus, allow the necessity for appliances specially designed to facilitate daily dressings to be regarded as unusual: the treatment of gunshot fractures thus tends closely to approximate to that of fractures in time of peace.

2. Limited immobilisation of the fractured area.—The real solution of this difficult problem is entirely due to Pierre Delbet, who set out to find a means of maintaining reduction without interfering with the movements of the limb. With this object, and to immobilise fractures without fixing the adjacent joints, he invented a series of excellent appliances which may be described as being an extensible external prosthesis, buttressed against the epiphyseal projections of the fractured bone, or other bony projections immediately adjacent to and intimately connected with it.

There are four types: *in the arm*, the appliance takes purchase above from a metal crutch in the axilla, and below from a curved plate on the flexed forearm; *in the forearm*, below from the lower end of the ulna and the radius, the trapezium and the unciform bone, above from a plaster surrounding the flexed elbow; *in the thigh*, the points of support above

are the ischium and great trochanter, below a plaster collar around the supra-condylar depressions; *in the leg*, above from the depression beneath the head of the tibia, below from the malleolar prominences.

The leg appliance is a continuous extension plaster; the other appliances are special instruments; those for the arm and forearm may be improvised by simple means; the thigh apparatus cannot be improvised; it is also difficult to apply, and painful if not very well applied.

These remarkable instruments will be discussed in connection with each individual fracture.

3. Fixation by Suspension with Continuous Extension.—This excellent method is being more and more widely applied, a state of things for which Blake is largely responsible. At first it appears complicated; it is actually very simple, but requires a good deal of supervision and careful attention to details.

Though applicable in all regions and easily improvised, it has the disadvantage of confining the patient to bed; for this reason its use in the upper limb has been restricted. It appears the most suitable method for the thigh, and also for the leg in certain fractures.

The principle consists in placing the limb in a hammock suspended from a frame by cords passing over a pulley carried on the frame, and kept in equilibrium by weights, while a continuous pull is applied in a suitable direction.

*The sling* for the upper limb is represented by two large diamond-shaped slings of soft material, 28 to 32 inches long and 4 inches wide, passing round the arm, one above and one below the fracture. The two extremities of each sling have slits through which the suspension cord passes. The latter passes over a pulley situated on the frame (which will be described later) in a line perpendicular to the fragments of the bone. The cord passes over a second pulley, and

supports a weight exactly counterbalancing that of the arm. The two fragments are thus fixed in suspension; their relative position is maintained in space without injury or friction.

In the forearm, thigh, and leg, the sling is represented by a series of narrow strips of material, stretched on a metal frame consisting of strip iron ·4 inch wide and $\frac{1}{8}$ inch thick. The suspending slings for the limb are 6 inches wide and 20 inches long; they are passed over the metal frame on each side and fixed with safety-pins. This arrangement allows easy inspection of posterior wounds; it is sufficient, in fact, to detach one strip by removing the pin to have access to the part of the limb which it is desired to examine.

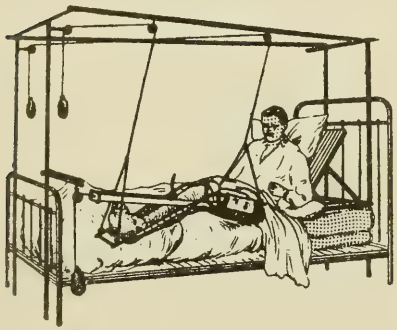


Fig. 38.—Suspension apparatus (see figs. 105 and 115).

If the wound is oozing at all, the strip in contact with the dressing may be replaced by rubber or by an aluminium plate moulded on the limb and supported by bending it over the edges of the metal frame: cleanliness is much facilitated in this way.

The four corners of the frame are fitted with small figure-of-eight hooks, to which the suspension cords are attached. The two upper cords unite 20 inches above the frame, the single cord thus formed passing over a pulley placed on the upper frame in a line vertically over the ends of the sling, or at a point slightly beyond it. Beyond this the cord descends, supports a sliding central pulley from which a weight is suspended, and unites with the cord from the lower end of the sling, which is formed in the same way and

passed over a pulley vertically above the lower end of the splint. The centre weight should exactly counterpoise the limb and keep it in suspension (see fig. 115).

I shall explain the exact arrangement in connection with each limb-segment : the above diagram (fig. 38) is sufficiently explicit for the present.

*The superstructure* is more or less complex according to what it is desired to do. In the most complete model it consists of a double frame, the vertical pillars of which, about 6½ feet in length, are prolongations of the bed-posts, and whose upper horizontal traverses are slightly longer than the bed. These pillars may be made of metal or of white wood. The transverse bars are notched or pierced at regular intervals : these holes or notches are intended to fix or receive longitudinal bars, movable at will, which are placed in line with the bed or with the limb ; they are themselves pierced by a series of holes at regular intervals, upon which pulleys may be hung. The latter are of the ordinary commercial type.

In other words, four vertical pillars support a horizontal frame, along which suspension pulleys may be attached in any direction desired. A perfectly balanced suspension is therefore obtained, which permits movement of all kinds.

In the most simple model, which is quite satisfactory in practice, although rather less convenient, two vertical supports, 6½ feet in length, support a horizontal bar which is placed in the line of traction desired, and from which the necessary pulleys are suspended. One at each end is sufficient ; over these, as has been said, pass suspension cords, which meet beneath a free central pulley supporting a weight.

The weight, which should be 4 to 8 kilograms for the lower limb, is provided by a series of sheets of lead or a bag of sand.

*Extension* is carried out on the ordinary principles, by means of adhesive strapping. Or again, the pull

may be exerted simply by means of a stirrup of soft material, which is applied methodically to the limb by a bandage. With some practice, perfect continuous extension may be produced in this way.

These appliances possess great advantages: they allow very easy supervision of the wound, the fracture, and of the whole limb; they greatly facilitate the dressing of the wound; they rapidly ease the patient, who is no longer in pain and is able to move in all directions, even to raise himself, and to move the limb very easily and without pain; finally, the suspension of the limb above the level of the bed makes nursing an easy matter, and makes for the physical hygiene of the patient. A further advantage is that they permit small movements of muscles and joints, and therefore favour recovery of function.

**C. Choice of a fixation appliance.**—It must not be supposed that there is a universal method of fixation, and one appliance which is better than all the rest for each type of fracture. Of the different types studied above, there is not one which is not indicated by particular conditions: to speak very roughly, the trough should be regarded as the temporary emergency appliance; plaster as the appliance for transport and convalescence; while Delbet's apparatus and its modifications, the suspension appliances, as those to be used for treatment.

**D. Duration of fixation.**—This should be regulated according to the fracture and the patient. In general, fixation is rarely too prolonged. Fixation, it is true, is severely criticised; it is made responsible for stiffened joints, muscular atrophy, and trophic disorders of the skin. But it is far from being proved actually to cause these, and its disadvantages are enormously exaggerated. When all is said and done, the advantage, from a local point of view, in allowing a case of fracture to walk too early is certainly not very great. The violence of the original injury, per-

sistent infection, and faulty reduction are the real causes of permanent loss of function; fixation prolonged for two or three months leads to no serious persistent trouble if the wounds are not septic. Immobilise a case of gonorrhœal arthritis for three months or a tuberculous joint for eighteen, and when the patient has recovered, the neighbouring joints will rapidly redevelop free play. If it is otherwise after a fracture, there is a local cause—distant osseous contusion, the formation of fissures, etc. In any case, the therapeutic method is not responsible.

After sub-periosteal esquillectomy, *even when the callus appears, both clinically and by X-rays, to have formed* (after forty to fifty days for the upper limb, sixty to eighty days for the lower), *fixation should be prolonged for a further twenty days at least, since the callus is not always very firm, and may become bent secondarily.* It is at this time that walking appliances should be used.

It should be considered a definite rule that sixty days' fixation is necessary for the upper limb, and eighty to a hundred at least for the lower.

**E. Delayed consolidation.**—If consolidation has not occurred at the end of this period, there is reason for adopting mercurial treatment (local dressings with calomel ointment), and for giving a little iodide. This often produces the desired result in a few days.

If there is no result, the surfaces of the fracture may be scraped with a curette. I have once seen a callus form very rapidly after this instrumental irritation.

Lastly, if everything has failed, I advise the immediate introduction of a metal suture, without waiting until the end of the period which is stated to elapse before pseudarthrosis * can be said to have

* Very recently in a fracture of the humerus after secondary esquillectomy which did not consolidate, I introduced a metal suture on the ninety-second day: at the first dressing, ten days afterwards, the callus had formed.

occurred, and particularly without waiting, as is the usual practice, for the wound to heal completely.

**F. Treatment subsequent to immobilisation.**—Massage, hot water, hot air, passive and active movements, should be introduced as early as possible. On the other hand, mechanotherapy is usually dangerous, and should not form part of the later treatment of fractures.

## CHAPTER XII

## FRACTURES OF THE HUMERUS

From the point of view of treatment, there are four types of fracture of the shaft of the humerus :

Fracture of the neck of the humerus ;

Sub-deltoid fracture ;

Fracture of the middle of the shaft ;

Supra-condylar fracture of the elbow.

These are obviously rather rough distinctions ; there are many types that are intermediate between these, but typical cases are still the more numerous, and in each of the groups mentioned there are characteristic peculiarities, which demand a special method of applying the general rules for treatment outlined in the previous chapter.

### I. Fracture of the Neck of the Humerus (Sub-epiphyseal Fracture)

1. Anatomical Features.—In the most typical cases, the direction of the fracture is transverse. It is clearly extra-articular at the level of the neck of the bone or immediately below it. The upper fragment, including the head and the tuberosities, is often prolonged down the front and outer side of the bone by a splinter of some length formed from the external face of the shaft at some distance from the biceps tendon, which remains intact on its inner side, or is torn away by the violence of the injury.

Fissures are very often found in the lower fragment,

and there is almost invariably severe injury to the cancellous tissue of the head of the bone. The cartilage is sometimes cracked, or even split clean across.

A greater degree of injury is the crushing of the epiphysis and shaft, dealt with in Part I (p. 103).

There are no large or adherent splinters; on the other hand, large numbers of small bony fragments are found, with a quantity of bone dust, which the injury scatters amongst the muscles over the prominence of the shoulder.

When the missile enters or passes out through the posterior region of the shoulder, at the level of the axilla, the circumflex nerve may be involved; the radial (musculo-spiral) is more often injured as it passes out of the axilla: the two ends of the nerve retract in opposite directions, and subsequent repair is always difficult and may be impossible.

2. Physiological Features.—Displacement of the upper fragment is caused by the muscles connecting the scapula with the tuberosity (supraspinatus, infraspinatus, and teres minor). As a result of their action, which is more powerful than that of other muscles inserted into the tuberosities, the upper fragment is abducted and externally rotated, that is to say, the head of the humerus gets out of contact with the glenoid cavity, and, with its cartilaginous surface downwards, rotates in the joint cavity, which is enlarged by expansion, and often lacerated at some point.

If the upper fragment includes the external splinter from the shaft to which I have referred above, this points backwards, and, entering the deltoid, threatens to pierce the skin.

On the other hand, the lower fragment, adducted by the latissimus dorsi, coraco-brachialis, and pectoralis major, and pulled upwards by the deltoid, assumes a position deep to the coracoid process. There is, in fact, very wide separation and displacement of the fragments.

3. Clinical Course.—There can be no question of the case running a course that does not require any surgical intervention: without operation infection is prone to cause the development of gas gangrene (since there are severe muscular lesions), osteomyelitis, or arthritis. Arthritis is almost unavoidable, in the first place because the infected bony region is in immediate contact with the joint, also because there are often fissures in the head of the bone which carry infection nearer and nearer to the joint cavity, and lastly because osteomyelitis of the upper fragment passes gradually upwards, and infection of the joint occurs after a few days through the ulcerated cartilage. I possess a specimen showing this last method of spread very clearly.

It is therefore always necessary in practice to intervene in order to prevent rapidly fatal complications.

What becomes of the fracture after an early operation?

Let us suppose a minimum degree of intervention, a *falsely conservative* operation (*i.e.* an attempt, which is ultimately unsuccessful, to preserve as much of the injured structures as possible) which is limited to the removal of the missiles, cleaning the approaches to the actual region of the fracture through the wound of entry or exit, removal of free splinters which the forceps happen to encounter, in a wound accessible with difficulty, *because nothing further appears at the moment to be necessary.* Let us suppose even a rather more comprehensive operation, which deals with the bony area, cuts off the sharp point of the upper fragment, and passes a drainage tube through the region: the prevention of serious and rapidly fatal sepsis is realised in this way, but chronic osteomyelitis will be unavoidable, the wound will suppurate profusely, and the joint will probably be invaded, owing to its contiguity.

This persistent septic condition will render it very

difficult, if not impossible, to achieve even an approximate reduction which will necessitate the extremely inconvenient fixation of the lower fragment in line with the upper, that is to say, elevation of the arm above the horizontal in a position of abduction and external rotation. It may therefore be supposed *a priori* that the reduction will be bad, and, as prolonged suppuration in a subepiphyseal region, where the periosteum is weak and thin, is always likely to cause pseudarthrosis, and also since there is often some muscular interposition, there will be every reason to expect a deplorable result.

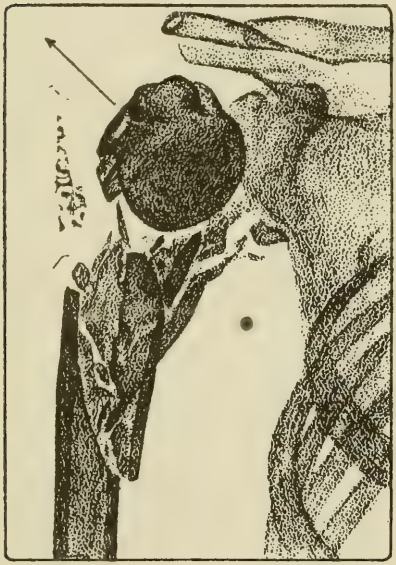


FIG. 39.—Radiograph of a subepiphyseal fracture of the head of the humerus, six months after the wound was received; treatment was limited to cleaning the soft parts and passing a drainage tube through the fractured area. Fœtid suppuration persisted, with very bad general condition, albuminuria, etc. I removed the head of the bone by the classical method; it was completely free and necrosed, with the cartilaginous face downwards, in an enlarged articular cavity full of pus. (See fig. 44.)

In fact numbers of cases, treated by inadequate methods, which escape the serious consequences of suppurative arthritis and juxta-articular osteomyelitis, are in a lamentable condition at the end of six or eight months; the head of the humerus, separated from its vascular connection with the shaft, becomes rarefied and almost translucent under X-rays; fœtid pus escapes through two or three sinuses, bulky periarticular callus produces a kind of circular ankylosis,

isolating the head of the bone, without producing satisfactory bony union between the epiphysis and the shaft.

To cure these unhealthy, wasted, sallow patients, a late secondary resection is required, the functional gain of which is necessarily very poor, since the muscles have become adherent and all the tissues round the joint are sclerosed and rigid. Totally different action must therefore be taken.

4. Indications for early Treatment.—*Fracture of the neck of the humerus should be treated early by typical sub-periosteal articular resection.* As soon as the diagnosis is confirmed by X-rays or by an exploratory incision of the exit wound, the *classical resection* should be carried out.

The joint is exposed by a rather low antero-internal inter-deltoid incision; the capsule being opened with a bistoury, the rest of the operation is performed with the cutting rugine (see Part I, p. 23).

Generally the intra-articular damage which will be found, and which the radiograph did not indicate, will cause surprise: the fissuring of the cartilage mentioned above will almost always be seen; often one or two small osteo-cartilaginous fragments will even be found free in the joint cavity.

The head of the bone is gripped by strong forceps and pulled outwards, while the sharp rugine carefully separates the periosteum and the capsule round the anatomical neck near the tuberosities and along the shaft splinter, if one exists.

There will be often some difficulty in gripping the head of the bone, which is no longer in contact with the glenoid fossa, but lower down and within an enlarged synovial cavity.

The lower fragment is thoroughly exposed and examined, and gently cleaned with the curette, or if necessary, trimmed with bone-cutting forceps.

The operation is concluded by careful cleaning of

the soft parts, excision of all loose muscular débris, and removal of any small splinters buried in the muscles.

The wound is left open; a drainage tube placed in the glenoid cavity passes out through a posterior counter-incision at the seat of election (see Part I p. 120. The anterior incision and the wounds of entry and exit are loosely plugged with gauze.

*Fixation* is ensured by a bandage binding the arm against the body; the case is then conducted like one of resection for articular fracture.

*Advantages of this method.*—No doubt this procedure will appear drastic: at the front, some surgeons will say that in the early stage it appears too drastic, since a restricted operation, ostensibly more conservative, is sufficient to prevent serious developments due to infection, to obviate disarticulation, or to prevent death; at the base, others will recall rare cases in which cure was effected with little trouble.

Neither, however, should forget that among the cases of this sort that they have seen there have been rapid deaths from gas gangrene, osteomyelitis, and acute arthritis, that an emergency operation for resection of the joint has sometimes become necessary on the third or fourth day, when the operation on the fracture had been performed only twenty-four or forty-eight hours previously; lastly, that numbers of cases evacuated still persistently suppurate, eventually requiring an extensive operation after months of suffering and repeated drainage.

In fact, the record of incomplete operations is frankly a bad one; these are the operations claimed to be conservative on the strength of a few fortunate cases which are rendered more prominent since the failures (deaths, disarticulations, etc.) are no longer there to darken the prospect.

Does early excision give better results? Decidedly.

It invariably prevents serious septic phenomena;

after it there are neither deaths from uncontrollable sepsis nor secondary disarticulations; under careful treatment *all* cases recover in a short time (forty days to two months). This is the first important reason, sufficient to prove that *intervention is truly conservative*. It has the disadvantage of removing too large a quantity of bone for function to be as well preserved as it may be after excision limited to the epiphysis.* But this does not mean that its results are bad. To appreciate them, conclusions should not be drawn from the very mediocre results of late excision. There is, in fact, from this point of view, a vast difference between these and excisions in the earliest stages; the latter, correctly performed, preserve the innervation of a healthy deltoid; asepsis having been achieved, all the muscle not directly involved in the original injury remains intact, and does not undergo permanent sclerosis; this muscle, moreover, actually retains its original action, since its origin and insertion are preserved. The rapidity of the cure allows massage and electrotherapy to be begun early, with the result that at the end of three or four months regular active exercise is possible. Further, if the operation has left the capsule and periosteum intact, ligamento-periosteal continuity is obtained, which has a great effect on the functional conditions, even if extensive regeneration does not occur. Owing to this, cases in which resection has been performed regain a very satisfactory use of the limb; the arm is certainly not rigidly fixed, but contraction of the shoulder muscles allows of fixation of the humerus; it is pulled upwards into contact with the glenoid cavity, and in that position the elbow can be abducted and the arm raised more or

* To judge the functional results of excision of the shoulder, it is essential to distinguish between resections limited to the epiphysis or joint, and those involving both it and the shaft. This distinction has not always been drawn in works which condemn excision in wounds of the shoulder as giving bad results.

less towards the horizontal, either outwards (action of the acromial fasciculi of the deltoid), forwards (action of the clavicular fasciculi), or backwards (action of the scapular fasciculi). Given the usual laceration of the muscle at some point, these three movements are not realised, so to speak, in perfection, since the combination requires an absolutely intact deltoid, but the arm is really active, and does not merely hang against the body, as in a case where the deltoid is paralysed by the original injury or a careless incision severing the circumflex nerve, or has been practically destroyed by prolonged suppuration.

It will perhaps be said that this optimistic picture does not correspond with the reality. It is certainly a picture of the favourable results only to be obtained by the correct operation on a vigorous subject, and by well-directed subsequent treatment. But account must be taken of cases of weaker physique, in which the operation and subsequent treatment have been technically faulty : excision of the head of the humerus performed at the front by the sub-capsulo-periosteal method demands careful attention from the surgeon in charge at the base hospital, and not the incomprehensible indifference, a justification of which is attempted by speaking later of the bad results of the excision. Cases in which I have carried out both the operation and the subsequent treatment until cure was complete have always given very satisfactory results. I recently looked after a case upon which Gayet and Truchet had operated, in which the functioning of the arm is remarkable, in spite of the loss of $3\frac{1}{2}$ in. of the bone. All the movements of the humerus can be performed to two-thirds of their normal extent.

Further, the worst results may often be bettered by humero-scapular ankylosis, by repair of the scapular muscles, or by an artificial appliance.

This discussion may be summarised in the following way : in sub-epiphyseal fractures, a solid callus with

ankylosis of the shoulder-joint and without a sinus is better than the result given by an extensive resection, but there is never any certainty of obtaining this favourable result ; a great risk is run, when the latter is expected, of attaining nothing, and resection is the only absolute guarantee against disaster. For this reason resection is in reality the truly conservative treatment : the average of results obtained by early resection *well performed* is very satisfactory ; having regard to the seriousness of the lesions, it is decidedly perferable to what one can obtain in any other way, provided always that the operation is undertaken early, and that it leaves the musculature intact ; sometimes its results are remarkable.

5. The Treatment of cases already under Treatment or seen at a late stage.—Four types may occur :

(*a*) *A case progresses well after a restricted operation confined to the fractured region and its immediate surroundings.* Every effort should be directed towards securing fixation in a good position. After X-ray examination, a plaster appliance is fitted, so as to fix the limb in a suitable position, that is to say, bringing the lower fragment in line with the upper. A plaster bandage should be used, and an opening made where the wounds are situated. If one of these is large, a bracketed interruption may be fitted, but the ideal arrangement for wounds which suppurate little or not at all is a plaster bandage round the upper limb and a plaster jacket, which ensures the best possible immobilisation.

For this purpose, the trunk is covered by a vest or by gauze padding, and a jacket is made by means of plaster bandages. It is useless to incorporate splints ; two or three bandages 5 yards long are enough to cover the chest with a moderately resistant casing, moulded over the shoulders and clavicles. When its thickness is considered suitable, a few figures-of-eight

are carried round the axilla, the strapping being passed from the shoulder on to the upper limb, and then down the arm and forearm as far as the metacarpus. The arm is fixed in abduction, the elbow being at some distance from the trunk, the forearm flexed in semi-pronation, and the thumb directed upwards.

Fig. 40.—Plaster with a window-opening.

When the upper limb is entirely covered by three regularly wound bandages, and as soon as the plaster has dried, openings are cut with a bistoury which will suitably expose the wounds. There need be no hesitation in making an opening sufficiently wide for the plaster not to be soiled; pads are slipped under the edges of the opening to prevent their disintegration, and an opening is cut to free the lower borders of the axilla.

This appliance is worn for about a month. At the end of this period, healing will generally be complete. The union of the bone is tested, and if it has occurred, the restoration of movement is begun.

If the wounds are more extensive, and require openings so large as to be incompatible with the solidity of the appliance, a bracketed plaster appliance should be used. This is constructed according to the fundamental rules of fixation, that is to say, it will fix the trunk and the elbow. That the arm may be well

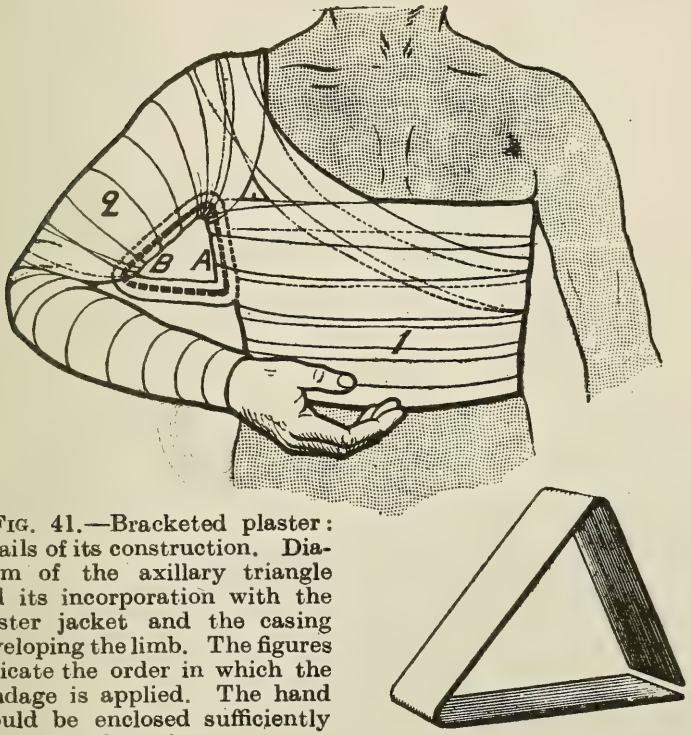



FIG. 41.—Bracketed plaster: details of its construction. Diagram of the axillary triangle and its incorporation with the plaster jacket and the casing enveloping the limb. The figures indicate the order in which the bandage is applied. The hand should be enclosed sufficiently to support the wrist.

sustained by a solid support, a metal triangle is placed in the axilla, made with a strip of metal bent in two places, or with any other rigid supporting material. Each side of this triangle is 6 to 7 inches long.

The appliance will include:

(i) A plaster jacket firmly enclosing the injured shoulder, made with three or four five-yard bandages.

(ii) A circular bandage enclosing the limb from the shoulder to the distal extremity of the metacarpals (three bandages).

(iii) A triangle of sheet iron, padded with wool fixed on with a gauze bandage.

(iv) An iron loop in the form of a bridge. This loop, the ends of which are slightly raised in order to pre-

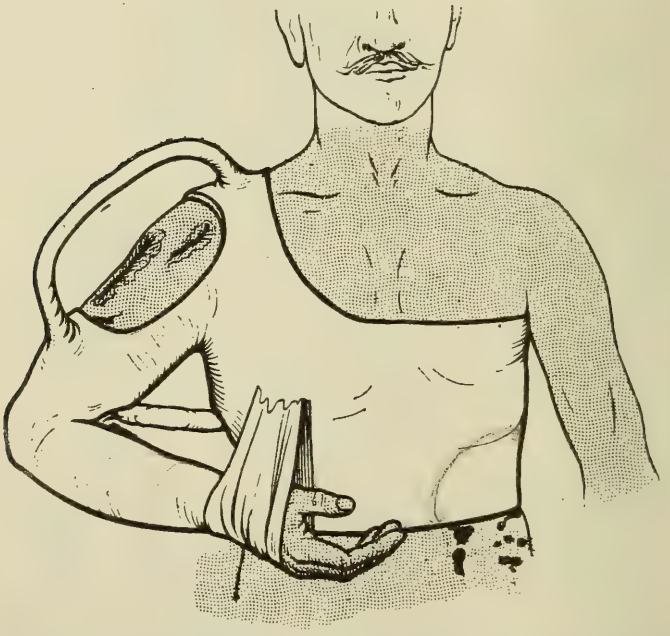


FIG. 42.—Bracketed appliance complete; a sling supports the forearm and hand.

vent slipping, is supported, above, beyond the coraco-acromial arch on the line from the shoulder to the neck, and below, at a point on the casing of the arm immediately below the wound.

The plaster jacket is applied first, the bandage passing over and including the thoracic side of the axillary triangle. When the latter is well fixed, the bandage is passed over the shoulder, and describes figures-of-

eight round the axilla and the neck, then is wound round the arm, binding the humeral side of the axillary triangle to it. This done, the enveloping of the elbow, forearm, and hand is carried out, these structures being fixed in the position already indicated.

Finally, the scapulo-humeral bracket is fixed in place on the plaster by another bandage, and nothing

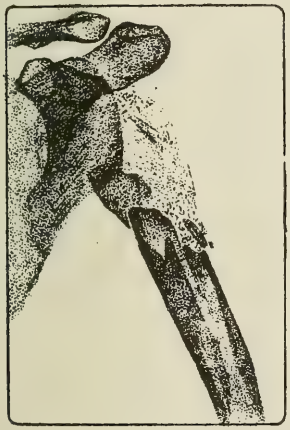


FIG. 43.—Radiograph fifteen days after extensive sub-periosteal resection of the shoulder done on the fourth day in a case of extensive injury to the epiphysis and shaft. The outline of the capsule and periosteum of the head is clearly visible.

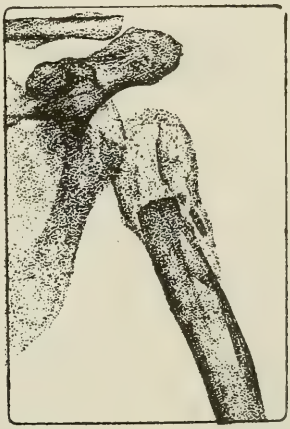


FIG. 43*a*.—Radiograph of the same case four months after resection: complete cure was obtained in two months, without pyrexia at any time. The satisfactory regeneration of bone in the injured region will be noticed. The functional result is excellent.

remains but to expose the region of the wounds and to trim the edges of the plaster.

(*b*) *A case arrives in a more or less septic condition, suppurating profusely, or with local signs of arthritis of the shoulder-joint.* Immediate sub-periosteal resection is necessary. It is certainly possible, by suitable incisions, to provide sufficient drainage to arrest the general symptoms, but it is impossible to

prevent slow necrosis of the head of the bone, which is becoming isolated in the articular cavity. Its removal should not be delayed until muscles have been destroyed and the patient's general condition is bad.

This late secondary resection is necessarily more drastic than if it had been done immediately, since the end of the shaft is also usually diseased. The functional result varies inversely with the muscular injury; if the musculature is still adequate, remarkable functional recovery may occur (figs. 43 and 44). The regeneration of bone is also almost always very complete, if care is taken to preserve the periosteum.

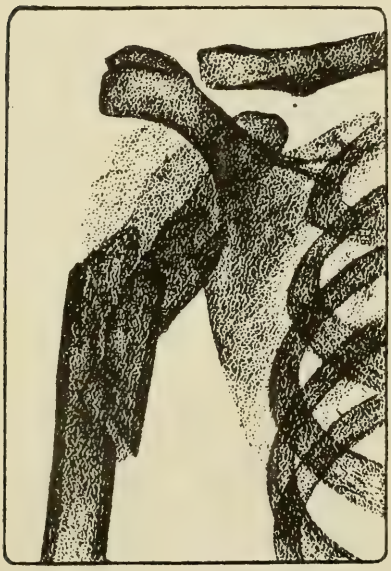


FIG. 44. — Radiograph four months after late sub-periosteal resection, in the case illustrated in fig. 39. A large bridge of bone formed from the periosteum unites the shaft with the glenoid cavity, and the shoulder is ankylosed. I did not attempt to restore movement on account of the complete disorganisation of the muscles.

(c) *A case arrives with sinuses.* The first step is an X-ray examination which will show accurately the real condition of the upper extremity of the humerus and the joint. In a few exceptional cases, union will have occurred, the joint will have remained free, and the only trouble will be superficial osteitis, with or without sequestra. Treatment should be limited to scraping the bone clean and removing sequestra.

But more often there is no callus and the fracture is suppurating, there are numerous dead splinters in the neighbourhood and in the joint, and the upper fragment

is obviously inflamed. Resection is necessary; the usual incision is made without regard to the position of the sinuses. Every effort is made to preserve the periosteum as completely as possible. It will often be necessary at the first dressing to sacrifice the biceps tendon, which is gangrenous and giving rise to suppuration.

(*d*) *A case is seen with pseudarthrosis.* Sometimes there is but little functional trouble, and there should be no interference, treatment being directed to development of the muscles. In other cases there is considerable trouble: if sepsis is not clinically evident, if the upper fragment is prolonged downwards by a splinter from the shaft, and if the joint is free, osteo-synthesis may be attempted after trimming of the fragments, but the operation is difficult to carry out and the result doubtful. If this intervention is not attempted or has failed, a prosthetic appliance must be used.

(*e*) *A case is seen with a flail-arm.*—It will be understood that there are two categories of flail- or useless arms: the active form in which the upper limb swings freely in repose, but can be fixed by muscular contraction when a movement is to be carried out, and the passive form in which the whole upper limb hangs absolutely useless.

The active flail-arm is, in fact, what it is attempted to produce by excision of the head and part of the shaft. The result is generally satisfactory, often remarkably so, even after extensive resection (fig. 43*a*), and there is no occasion for interference.

On the other hand, a passive flail-arm is a serious infirmity, which not only destroys the function of the shoulder, but greatly interferes with that of the forearm and hand. Contrary to what is usual in the elbow, it is not always possible in this case to redevelop by prolonged massage sufficient muscle to support the arm. Recourse should then be had to

the use of a prosthetic appliance, which gives a very fair result.

Attempts may also be made to improve the situation by effecting humero-glenoidal fixation, humero-clavicular suspension, or the double humero-coraco-acromial suspension which Ollier practised.

I have no experience of these and cannot say what is actually effected. But according to the fullest information I possess, I believe this solution infinitely preferable both to any grafting that the surgeon might be tempted to effect (graft from the fibula) and to osteoplasty by reduplication of the humerus, which is technically much more difficult and apparently less reliable in its results.

### II. Sub-deltoid Fracture

1. Anatomical Features.—This is a fracture situated in the upper third of the humerus, of such a nature that the lower fragment of the shaft is absolutely or nearly intact, below the insertion of the deltoid. The fracture is often comminuted; the shell-fragment or bullet has, as it were, entirely removed the bone below the insertion of the muscle, with the result that the deltoid acts unrestrainedly on the upper fragment.

In other cases there are large, very oblique splinters, but this is less common.

As a rule there are no radiating fissures or accompanying vascular and nervous lesions.

2. Physiological Features.—The deltoid pulls strongly on the upper fragment and abducts it; its lower end is thus found to be raised and deflected outwards, with the medullary canal directed outwards, while the lower fragment remains in place, embraced by the brachialis anticus. The angle formed by the two fragments, which is about 45°, is incomplete on

its inner and posterior aspect; it is here that small fragments and bone dust are found.

In some fractures the opposite displacement occurs, the upper fragment being pulled strongly inwards and internally rotated (fig. 46). This displacement is due to partial laceration of the deltoid insertion, giving predominance to the action of the pectoralis major; this muscle then pulls the upper fragment into a position such that fixation should be effected with the elbow and arm made fast to the trunk, and vertical extension by weights as indicated in fig. 60.

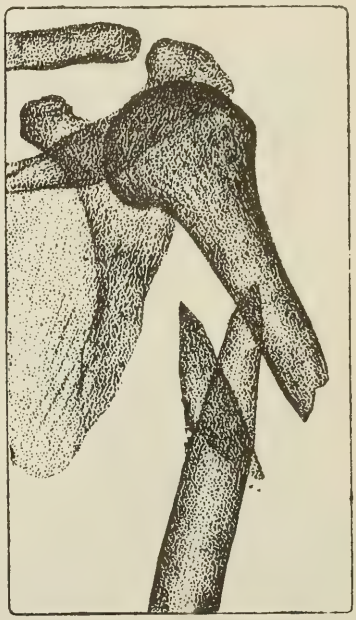


FIG. 45.—Low sub-deltoid fracture: the position is usually higher in the shaft.

3. COURSE. — Infective lesions here are similar to those met with in any other region; what, however, characterises this fracture is the impossibility of manual reduction; the angulation of the principal fragments persists indefinitely, if it is not corrected by placing the lower fragment, which alone can be moved, in direct line with the upper. Pseudarthrosis sometimes results, particularly in comminuted fractures and when the wound suppurates; the infection then destroys the activity of the periosteum which alone can produce material to bridge the gap.

When, on the other hand, the infection is slight (in fracture by bullets causing only small cutaneous wounds), union occurs, but with marked deformity (antero-external angulation) and marked shortening.

4. Indications for early Treatment.—Sub-periosteal esquillectomy is necessary here as elsewhere in order completely to prevent sepsis; the thick muscular layer surrounding the injury makes the danger of the development of serious infection in a closed cavity very serious.

In performing the operation, the fracture should preferably be approached by an antero-internal incision, the muscle fibres being separate in order to reach the bone; a posterior incision might result in severance of the circumflex nerve, and therefore in permanent paralysis of the deltoid, which should be avoided. The entry and exit wounds should be cleaned, but drainage is carried out through the incision. Bone débris should be removed with minute care, the muscle being often riddled with it. In this, however, there is nothing peculiar.

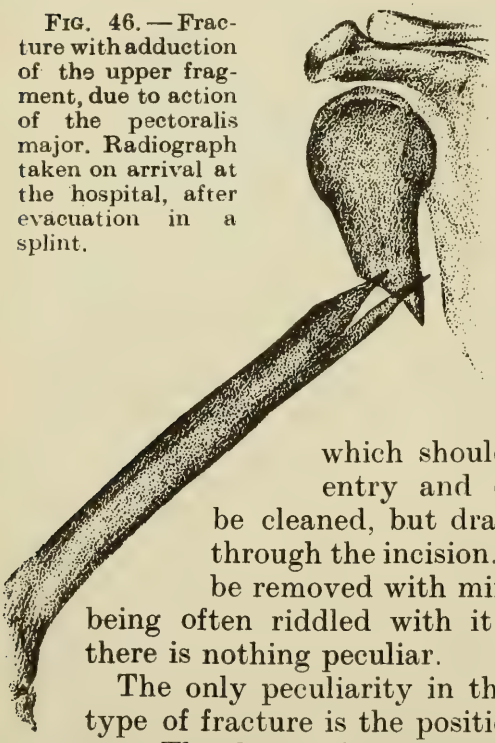


Fig. 46.—Fracture with adduction of the upper fragment, due to action of the pectoralis major. Radiograph taken on arrival at the hospital, after evacuation in a splint.

The only peculiarity in the treatment of this type of fracture is the position in which it is put up. The lower fragment, which is movable, whereas the other is not, is brought upwards and outwards into line with the upper fragment, and the arm is immobilised in this position.

This can best be done by means of a plaster apparatus constructed in one of the following ways, both of which I have employed several times.

(*a*) *If the wounds are large.* The appliance should

leave the arm exposed, merely supporting the lower fragment in line with the upper. This plaster consists of five pieces :—

(i) A thoracic belt which is applied first.

(ii) Two braces, one as broad as the palm of the hand, and passing over the uninjured shoulder; the

FIG. 47.—Plaster apparatus for immobilising the arm in an abducted position. The two small sketches are copies of radiographs taken before and after application of the apparatus in the particular case illustrated. The figures indicate the order of application of the different pieces of the appliance.

other much wider in its centre where it covers the injured shoulder.

(iii) A trough for the forearm, embracing the elbow and passing some distance above it. A plaster bandage is wound round these different pieces to unite them.

(iv) A metal splint (*e.g.* a small wire splint such as is found in the field-service outfits) bent at an acute angle in the middle, which is incorporated horizontally in the chest plaster by means of a plaster bandage (figs. 47 and 48). Its object is to support the lower fragment in the position of abduction.

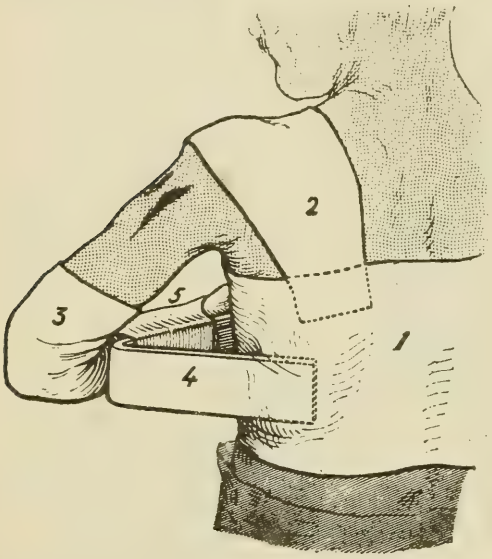



FIG. 48.

For the first few days three or four wooden splints are fixed by strapping over the dressing, to secure better immobilisation of the fragments, as is shown in fig. 60.

This excellent appliance is kept in place until union occurs. If it should deteriorate, another of the same type is made, or the appliance described below may be employed.

(*b*) *If the wounds are not extensive*, an apparatus is made with plaster bandages in the following way:

A well-fitting plaster jacket is first made, covering the injured shoulder (three or four bandages 5 yards in length), then one is made to cover the upper limb, supported in a position of abduction.

To maintain it in this position I used to consider a bent iron loop necessary, surrounding the elbow and fixed to the thorax. For some time I have replaced this by a sort of plaster bridge, made of several thicknesses of bandage, and kept stretched between the elbow and chest by an assistant until it has set.

A few turns of a plaster bandage make this bridge solid and unite it with the rest of the appliance ; it is much lighter when made thus.

It is safer to include a second plaster support connecting the elbow with the lower edge of the jacket (see fig. 49).

A rigid axis of wood or cane can be incorporated

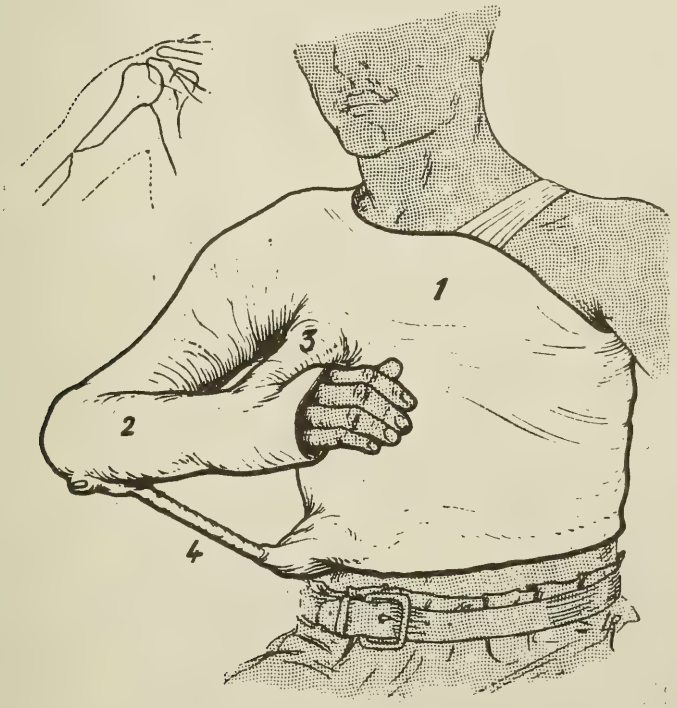



FIG. 49.

with great advantage in the two plaster bridges : an ordinary ruler makes an excellent support. It is also possible to use the arrangement described on p. 393 .

If the patient has to be kept in bed, the best method is the suspension appliance which will be found described in fig. 65, p. 428 , traction being exerted in a position of abduction, which is easily arranged.

5. Indications in cases already under Treatment or seen at a later stage.—(*a*) *An evacuated case in which esquillectomy has not been done is going on well at the end of five or six days.* If there is no infection, no suppuration, and no foreign body present, it is only necessary to immobilise the limb in a good position.

(*b*) *A case, in which there has been an incomplete operation, or none at all, is still suppurating profusely when seen during the first three weeks.* After X-ray examination, by which the position and features of the lesion are determined, free esquillectomy and drainage is carried out, and the limb is immobilised as after a primary operation.

(*c*) *A case is found to be suppurating, but union is beginning.* An operation on the bone is probably inadvisable. The best course is merely to drain and remove free splinters, but it is not the time to interfere with adherent splinters and to injure the infected bony area; at this stage any course that is in the least drastic is dangerous. It is better to wait for the later stage of sinus formation, when the patient's condition is less feeble probably because the medullary canal has become shut off.

(*d*) *A case is seen with a sinus.*—This is almost always due to a free splinter, which is more or less enclosed and unable to escape. There is rarely a central sequestrum, and the operation is generally easy.

(*e*) *A case is seen with pseudarthrosis.*—This is almost always due to want of reduction, and the condition justifies forcible reduction with metallic osteosynthesis by Lambotte's method or by wiring.

### III. Fracture of the Middle of the Shaft

1. Anatomical Features.—Of all the fractures of the upper limb, these are the most frequent.

Two principal types exist, that accompanied by large

splinters and that marked by small splinters; each of these exhibits the general features discussed on p. 281

In the large-splintered type, which appears more common than the other, there is either roughly the butterfly-wing arrangement described by military surgeons, or extensive lateral splintering, opening the medullary canal and impossible to describe owing to its variety (fig. 5); often in this case, the missile, being spent, stops in the medullary canal; the majority of the splinters are originally adherent and fixed, but free particles of bone are constantly found in the medullary canal.

In the comminuted type, nearly the entire segment of bone injured is shattered into débris and projected into the muscles, or left as adherent splinters rotated upon their own axes: the largest fragments are scarcely more than 2 inches long, and they are the least numerous; in fact, little is left between the two fragments of the shaft, and the actual gap is almost always about 2 inches wide.

*The peculiarity of these two types is the extreme frequency of nervous lesions, and particularly of radial (musculo-spiral) paralysis.* It is difficult to give an exact figure, but this complication is found in one out of four cases, if not in one out of three. The nerve is most usually severed, and, to judge by my own observations, generally in the classical position, that is to say, in the musculo-spiral groove.

Paralysis of the median, or of the ulnar, or of both may also be found.

The nerve injury is sometimes a complete severance, sometimes lateral laceration, sometimes simple contusion with interstitial hæmorrhage.

In a number of cases there is associated injury to the lung, the same projectile having fractured the humerus and passed into the thorax.

2. Physiological Features.—In comminuted frac-

tures there are none ; owing to the extensive destruction of bone and rupture of surrounding muscles, little displacement of the fragments occurs.

In large-splintered fractures it is unusual for the upper fragment to tilt forwards (action of the deltoid) and perforate the brachialis anticus. This only occurs in the high fractures studied in the preceding section. On the other hand, the lower fragment is pulled up by the triceps and has a slight tendency to backward and upward displacement ; this upward movement is often scarcely perceptible, and a more prominent feature is angulation with its apex pointing backwards. A single radiograph is not sufficient to make this out ; the topography of a fracture can only be appreciated from two plates, one lateral, one antero-posterior. In any case, however, the displacement is slight, the fragments, enclosed by the brachialis anticus, remaining in place.

3. Course.—We will put aside grave and rapidly developing sepsis, causing death from gas gangrene, or necessitating early amputation for acute osteomyelitis. A few uncommon fractures * are seen at the base, which run a simple course from first to last without operation, in which the shell-fragment traversed the bone without leaving anything behind it : such cases are exceptional.

After an operation reduced to what is strictly necessary to prevent the most serious septic phenomena, persistent suppuration generally follows, with purulent tracks along the biceps and brachialis anticus. The local development of suppuration necessitates repeated drainage ; repeated searches are necessary for dead splinters, which make their way towards the orifice of the wound, and the patient, after fifteen or

* I remind the reader that fractures by a bullet which has caused "punctiform" cutaneous wounds are not within the scope of the present study, and that in such cases an uneventful course leading to satisfactory union, after fixation and extension, is the rule.

eighteen months, shows with pride and satisfaction all the pieces of bone which have been removed from his wound.

At the end of two or three months of suppuration the fracture may be in one of the following different conditions :

(*a*) *Consolidation and complete healing.*—If continuous extension has been well effected, reduction is generally satisfactory and the anatomical result is good ; physiologically, the power of the functional muscles is more or less reduced by inflammatory sclerosis and a long period is required for the re-establishment of their normal contractility, but the final result would be very passable if the callus were not large, and often misshapen : it is almost always a badly formed callus, bearing traces of the infected medium from which it has been developed. This is not without importance ; when an operation is performed in the immediate neighbourhood of the fracture with the object of freeing or suturing the radial nerve, all the tissues round the bone are found to be lardaceous and fibrous ; often in dissecting the nerve on the surface of the bone, small superficial osseous cavities are opened, enclosing a small sequestrum surrounded by more or less serous but not virulent pus. The whole region gives the impression of pathological tissues of poor quality. In fact, recurrent fractures are not unusual ; it would, indeed, be surprising if they were.

Briefly, an apparently good result, but with every chance of trouble in the future.

(*b*) *Consolidation with superficial osteitis.*—After five or six months there remains a small sinus covered by a superficial scab and continually oozing small quantities of sero-purulent fluid. It is customary to wait for this to heal of its own accord. I have seen several which persisted for fourteen, sixteen, or eighteen months, and in the majority of cases, associated radial

(musculo-spiral) paralysis had been left without intervention because the wound was not aseptic. Usually a small area of superficial osteitis is concerned, or a small marginal cavity enclosing a sequestrum which cannot escape. Cure can usually be effected by a simple operation.

(*c*) *Union by a redundant callus with a central cavity.*—This is the typical case of pathological consolidation described on p. 302 Passing through the thick periosteal bone, a sinus leads into a cavity, at each end of which is a mass of condensing osteitis closing the medullary canal. The lesion is not spontaneously curable, and is difficult to cure by operation. The prospect for these patients is poor, and the surgeon should not be sanguine of functional recovery. There is every likelihood of frequent outbreaks of sepsis necessitating successive operations.

(*d*) *Pseudarthrosis.*—The absence of union (as apart from its delay) occurs in two conditions, in each by a different process.

In comminuted fractures, in which a segment of the shaft has been pulverised, the marrow is destroyed, and the periosteum very nearly so. Unless asepsis is assured, the remains of the bone-forming tissue on the under surface of the periosteum is destroyed by the infection : rarefying osteitis develops in the ends of the shaft, a certain amount of fibrous and lardaceous tissue becomes interposed between them, and no spontaneous fusion is possible. This is pseudarthrosis by destruction of the tissues which should effect repair.

In large-splintered fractures it often happens that when the appliance is fitted, the splinters which have been left in place, closing in on the long axis of the bone as a result of continuous extension, enclose a more or less isolated fragment of muscle which becomes interposed between the fragments of the shaft, and mechanically prevents spontaneous repair. At the

same time, the marrow is destroyed by infection, the periosteum is rendered inactive, and the ends of the shaft undergo necrosis. In a case of this kind I was able to remove a piece of bone which demonstrated this very well. It was built up in the following way: in the centre was a piece of the brachialis anticus ½ in. in length, caught below on a sequestrum completely covering the soft and spongy lower end of the shaft, and surmounted by another semi-annular sequestrum covering the upper extremity of the shaft, which was also the seat of rarefying osteitis.

These two types of pseudarthrosis are not of rare occurrence, and the majority seen at the base are of this kind; it is wrongly concluded that the humeral periosteum is comparatively non-fertile. The fact of the matter is that amputation is less frequently performed for fractured humerus than elsewhere since the phenomena of sepsis are less serious in the humerus than in the thigh where the muscular covering is much thicker, and also less severe than in the forearm and leg, where the presence of tendons and their sheaths may lead to serious secondary complications.

4. Indications for early Treatment.—There is only one way of assuring a sure and regular course towards a definite, anatomically and physiologically perfect, cure and of preventing all the troublesome developments described above: that is to perform free sub-periosteal esquillectomy as early as possible. This prevents the development of any signs of infection, and thoroughly clears the bony surfaces. Perfect reduction of the fracture is thus facilitated, without allowing the slightest possibility of muscular interposition; at the same time all the elements necessary to repair are preserved in the wound.

When this operation is carefully performed in the correct manner, that is, with the sharp rugine, the constant result is permanent asepsis; this facilitates fixation of the fracture in simple appliances by which

reduction is easily effected by continuous extension. The three stages of treatment, preventive disinfection, reduction, and fixation, are carried through without hindrance; the patient may be evacuated very soon, and union occurs rapidly (thirty-five days to two months).

5. Operative Technique.—(*a*) *In Esquillectomy.*—(i) *Method of approach.*—The topography of the fracture and the position of any missiles should previously have been determined by X-ray examination, or if possible from a radiograph. There are two available ways of exposing the fracture, according or not as the size and position of the wound provides a way of access.

If the exit wound is large, and not in immediate contact with vessels or nerves, the track of the projectile is followed in the reverse direction, the cutaneous orifice being enlarged if necessary, and the track carefully cleaned; two retractors are placed in position, and any lacerated or dead tissue, all free bony fragments, and all foreign bodies, are removed with forceps. A bistoury is then used to excise any fascia or muscle that it may be necessary to remove in order to prevent closure over the fracture or the retention of any obviously contused tissue. This will sometimes involve enlargement of the cutaneous incision. There should be no hesitation in doing this; the external wound is of little importance, the main point being to discover all the lesions and thoroughly to expose the fracture.

If the cutaneous wounds are small, inconveniently placed, or in contact with nerves or the brachial artery, or in such a position that subsequent care of the wound will be difficult (*e.g.* an axillary wound), the bone is approached by the route of election, that is to say, by an incision over the outer side of the arm between the biceps and the outer head of the triceps.

The bone being exposed, an intact periosteal sheath

will generally be found, particularly in large-splintered fractures; this is incised along an adherent fragment, the incision being begun at the point where the shaft ends, and the rugine is used carefully to free the periosteum on each side of the incision; in this way it is easy in the majority of cases to free a considerable periosteal cavity without actually having removed any adherent piece of bone.

(ii) *Extent of the Esquillectomy.*—Following the usual rules indicated on p. 345 free and loosely adherent splinters are next removed, and when the region of the fracture has been cleared, a further investigation should be made. The object of this, as has been stated before, is to expose any area of medullary contusion, in order to explore the injury completely and to leave behind nothing suspicious.

In large-splintered fractures, this will often lead to the removal of a very adherent postero-external splinter lodged beneath the triceps and corresponding in position to the origins of the inner and outer heads of that muscle, to which it is firmly adherent; very near to this is the radial nerve in the musculo-spiral groove or immediately below it. It is of great importance to detach this very carefully: I make a regular practice of doing so when such a fragment exists, regarding this as the best means of avoiding subsequent involvement of the nerve in the callus, an accident that is very liable to occur, since the nerve generally lies in immediate contact with the fissure, and crosses the fragment like a bridge. In doing this, there is no fear of injuring the nerve if the periosteum is respected; the process is identical with that of liberating the ulnar nerve in resection of the elbow joint: in this way the nerve is pushed beyond the interosseous gap, and will not be involved in any subsequent periosteal proliferation. Further, during this freeing of the nerve, a small missile is sometimes found concealed by one edge of the fragment, which

otherwise would certainly have escaped notice. I am not speaking of the very small free splinters which may also be found, and whose presence explains those little residual abscesses often found near the bone during a later operation for radial paralysis.

Finally, after the operation, the only bone left in the injured region are the two pointed ends of the shaft, in contact at their apices: this I believe to be an excellent result. An examination of the injury to the bone will show that the space left empty by the removal of splinters is enclosed by a hollow cylinder of periosteum, the mould, as it were, of the future callus. In comminuted fractures, there are usually at the periphery short and adherent splinters connected with the shaft above and below; any of these should be removed with the rugine which are situated near vessels or nerves, particularly the radial nerve. When the esquillectomy is completed, there is an interfragmentary gap of about 1½ inches, in which hang fragments of periosteum: the ends of the shaft are generally oblique and rather ragged. Gentle cleaning of the medullary canal with a small curette should complete the operation. For this purpose it is not generally necessary to proceed further up than the area exposed by the removal of adherent fragments. It is advisable to remove the sharp points of the ends of the shaft with cutting forceps; in doing this, great care should be taken not to interfere with the periosteum by pushing it aside before applying the bone forceps; otherwise, what has previously been preserved is lacerated, and there is a risk of spoiling the work of the rugine.

*Dressings.*—The wounds of entry and exit being cleaned according to the usual rules, and missiles in the neighbourhood of the fracture being removed, the wound is plugged with aseptic gauze. There should be no strip of dressing, and above all, no drainage tube, passing through the wound from one side to the

other: gauze is placed very loosely in the medullary cavity, in the operative incision, and in all other wounds, which should be left widely open. All suturing should be avoided; there is no advantage in partially closing the cutaneous wound at each end, as is so often done: it is never cutaneous healing which retards cure, but deep healing, which suture will not hasten.

FIG. 50*a*.—Large-splintered fracture with bony fissures, caused by a shell-fragment.

FIG. 50*b*. — Radiograph showing the result of early sub-periosteal esquillectomy and continuous extension applied to the elbow.

For *fixation* purposes, I merely flex the elbow and apply the arm to the chest, which is padded with sterilised wool, and bind it there with soft bandages, an arrangement identical with Velpeau's bandage employed after reduction of a dislocated shoulder. Care should be taken to place a small pad of absorbent wool sprinkled with sterilised talc in the axilla, and to pad the elbow well. This bandage is left in place for several days when all goes well; I have sometimes not touched the dressing before the eighth day.

I always change the first dressing under an anæsthetic (ethyl chloride): in this way pain is avoided,

the wound can be examined better, small omissions in the operation can be made good, and the gauze can be placed more exactly where it is required.

If anything necessitates its being repeated later (pain, considerable oozing, or pyrexia), a similar bandage should be re-

FIG. 51.—Total sub-periosteal esquillectomy was performed eighteen hours after the occurrence of this fracture.

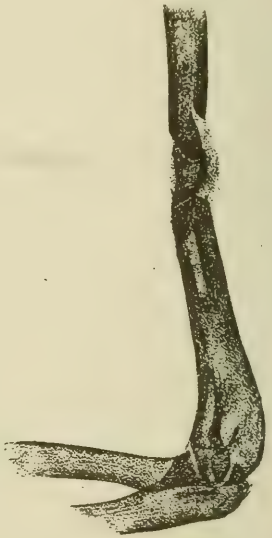


FIG. 52.—Result after two months; the wounds have closed, after daily heliotherapy.

applied, and the same temporary fixation arranged: it is advisable not to use a permanent appliance until a regular course of recovery is certain; moreover, well cleaned recent wounds progress well with infrequent dressing. If the case has to be evacuated rapidly, the dressing should be performed on the day previous to that fixed for the evacuation.

For transport a plaster trough covering the shoulder with two small thoracic flaps should be applied. But

this is only a travelling appliance, to be removed on arrival, and is not intended for treatment (fig. 53).

(*b*) *Permanent Reduction and Immobilisation.*—When free esquillectomy has been done, reduction practically follows, and the fracture will unite in the correct position after simple fixation in a plaster splint, provided that the correspondence of the long axes of the fragments has been verified by the X-rays. But if the quantity of bone lost is not great, continuous extension gives a better result since the reduction is more perfect, the fragments are kept well apart and therefore there is no shortening.

FIG. 53.—Plaster apparatus for travelling.

Let us examine the two cases :

(i) *When there is limited loss of bone.* Here there is juxtaposition of the fragments without loss of length in the bone; over-riding is possible and reduction is necessary.

Continuous extension and fixation can be effected by one and the same apparatus, such as Delbet's appliance, or one of its modifications (Leclercq's appliance) or with Alquier's crutch.

In Delbet's appliance the *extension* is exerted above by means of a curved metallic axillary support, padded with cotton wool, and below by a semicircular metal

plate over the upper end of the forearm, the elbow being kept flexed at right angles by a plaster bandage. A hollow rod is hinged to the forearm plate, and within it slides a solid rod connected with the axillary crutch.

Traction is exerted by a spiral spring which forces the two shafts apart, and these latter are pierced by holes into which a pin can be introduced,

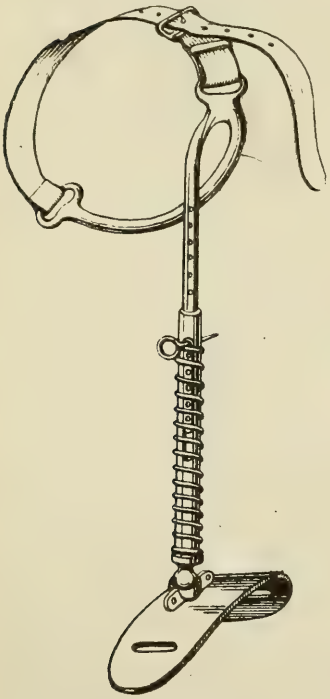


FIG. 54.—Delbet's appliance.

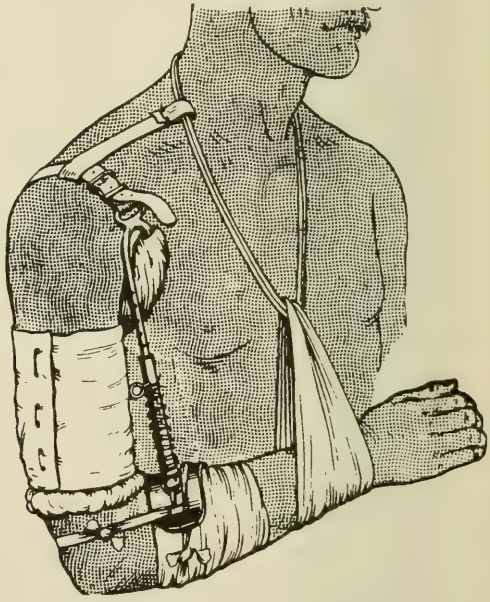


FIG. 55.—Delbet's appliance in place.

and by means of this the spring can be shortened and extension consequently regulated.

This appliance is excellent; sometimes it is a little painful, particularly in fractures high up, where, on account of correction being more difficult, there is a tendency to employ an undue amount of extension, but the reduction of serious displacements can be effected by it. It has the further advantage of leaving the injured region exposed, and of allowing slight

movements of abduction of the arm, and of supination and pronation of the forearm.

When the fracture has been properly set and the correct pressure ascertained, the care of the apparatus is simple; attention should be given to the condition of the skin of the axilla, to which a zinc oxide paste should be applied as a precautionary measure in fat subjects. Particular attention should be devoted to the position of the forearm, which should remain flexed at a right angle; if the angle becomes obtuse, the support slips and extension ceases. The appliance should not be removed until union has occurred.

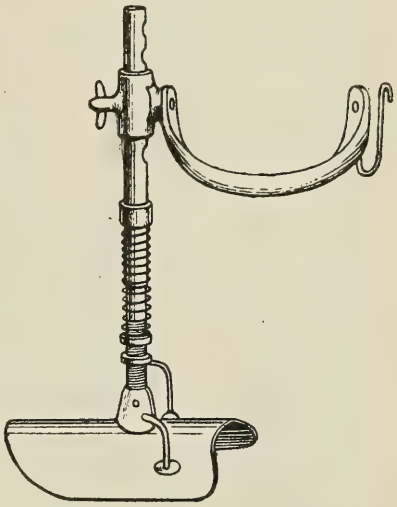


FIG. 56.—Leclerq's appliance.

Leclerq has modified Delbet's apparatus, rendering it interchangeable for the right and left arm. The semicircular axillary support which he employs is wider and longer, and derives support also from the thorax; the lower plate is also wider. The principle is the same; the results are equally good; the disadvantage—that the appliance cannot be improvised—is the same. War surgery requires that it should be possible to construct the necessary appliances on the spot, by simple means and from elementary materials.

Alquier's appliance fulfils these conditions: working upon Delbet's idea and the form of his apparatus, he has given a very practical and interesting solution of the problem.

His appliance can be constructed very easily any-

where and in a few moments, from two iron slats each rather longer than the arm. The upper part of one of these is divided longitudinally into two pieces 5½ in. in length, which are then separated and twisted in such a way as to from a sort of *curved crutch*. The lower part remains as a straight shaft, and is pierced with four holes through which bolts may be passed. A slot is cut out in the upper part of the second slat, while the lower part is bent up in the form of a loop. The crutch is padded with cotton wool surrounded by a flannel bandage and covered with mackintosh. The appliance is then ready. To apply it, a circular plaster bandage is first applied to the forearm from a point slightly above the elbow down to the hand, fixing the elbow at right angles ; it should be moulded round the projections of the elbow. When the plaster is dry, the padded crutch is placed in the axilla, the straight shaft is placed parallel to the internal surface of the arm, and the semicircle of the lower piece is then fitted to the (posterior) under aspect of the elbow, to the outline of which it should correspond exactly ; the straight shaft passes upwards in contact with the arm and with the upper piece. A few turns of a plaster bandage fix the curved piece to the elbow, and when the plaster is set, traction is applied. For this purpose a weight of 4 kilogrammes is suspended from the flexed elbow for half an hour, a short counter-

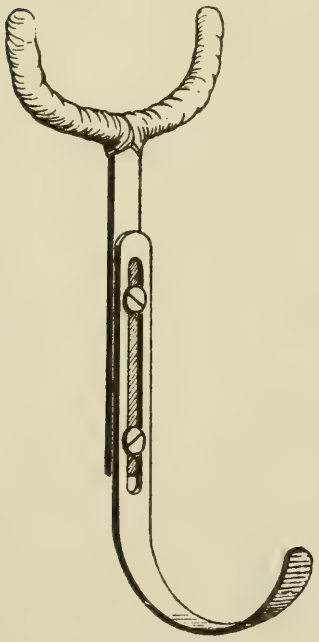
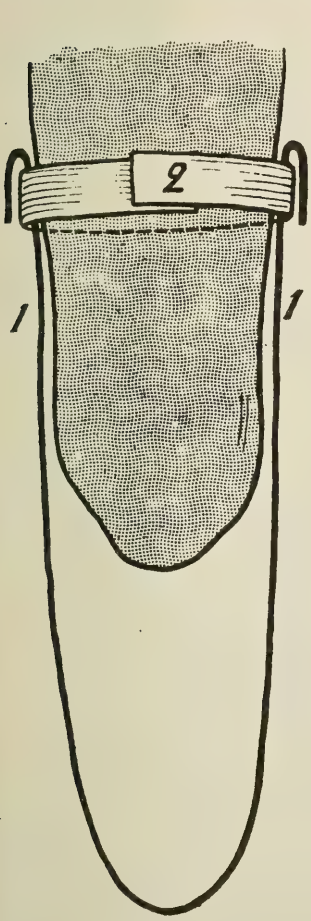
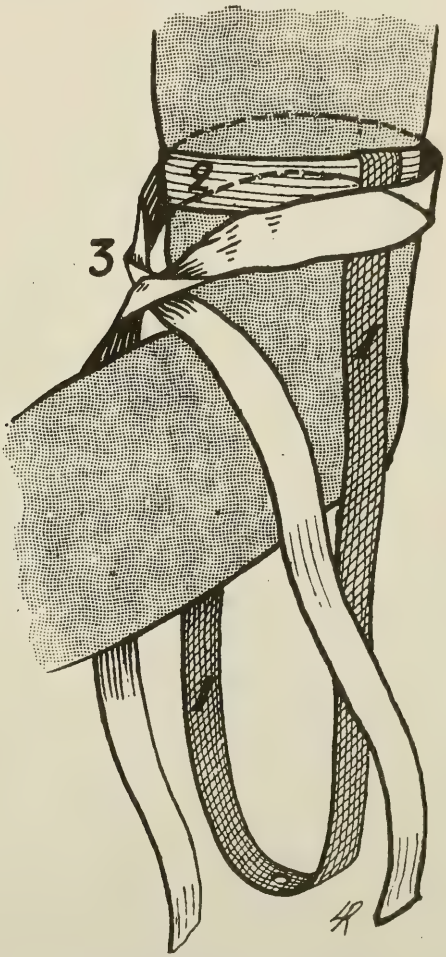


FIG. 57.—Alquier's appliance, with the crutch padded.

extension being applied in the axilla. When muscular contraction is overcome and the fracture reduced, the nuts are screwed up, and nothing further is necessary but to remove the extension and counter-extension.




FIGS. 58 and 59.—Method of arranging the bands for extension.

I regard this appliance as one of the best, if not the best, of all that have been suggested. It is simple, reduces well, does not interfere with dressing, and is

perfect for evacuation: in fact, I consider it the ideal appliance for the front.

At the base, the purposes of treatment can be fulfilled in an equally perfect way, and still more simply.

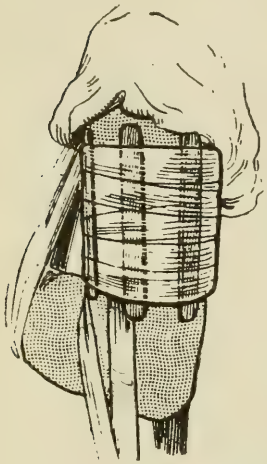


FIG. 60.—Extension effected, with a weight of 1,200 grammes.

In these fractures, particularly after esquillectomy, the displacement is not marked, since the fragments are not under the influence of powerful muscular action; further, when the patient is standing, gravity itself tends to reduce angulation; in fact, *the lower fragment is virtually in continuous extension*; exaggeration of this tendency, effected by suspending a weight above the elbow, is enough to reduce the displace-

ment. On the other hand, permanent continuous extension, if it may so be described, is not necessary for the maintenance of reduction, and intermittent continuous extension (to use paradoxical terms) is sufficient if repeated regularly. This was so in the case of oblique fractures in peace-time ; it is equally true of war fractures. I have regularly employed a very simple continuous extension procedure based on these theories, which is in constant use at Lyons for simple fractures. Like Bérard and Desgouttes, who have also used it, I have obtained excellent results.

With this apparatus, extension is only active when the patient is standing and the elbow is against the side, but experience shows that this is sufficient.

The apparatus is simple. It consists in applying continuous extension by weights above the elbow, and in keeping the fragments immobilised by fixing three or four narrow wooden splints over the dressing by means of a bandage which holds everything together and immobilises perfectly (see fig. 60).

There are several methods of effecting extension :

($\alpha$) The weight of the lower fragment may simply be increased by winding round it a sheet of lead (800 to 1,000 grammes), in the form of a figure-of-eight, the upper loop of which surrounds the humerus and the lower the elbow.

($\beta$) A collar in the shape of a figure-of-eight may be applied, identical with Hennequin's used for fractures of the thigh ; this is made of linen or similar material, and a suitable weight is hung from the lower loop.

($\gamma$) Lastly, regular traction may be effected by means of adhesive strapping : this is the method which I usually employ ; it is more exact since the pull can be exerted in a slightly anterior or posterior direction when X-ray examination shows this to be necessary.

The patient being seated, and the elbow flexed at a

slightly acute angle, a loop of strapping is first applied in the shape of a U, the vertical limbs passing vertically upwards on each side of the elbow and arm as far as possible, exactly parallel to the long axis of the shaft. To ensure more perfect adhesion, the upper bands may be cut into short strips and splayed out on the arm. This done, the vertical loop is fixed by means of a circular piece of strapping over which the upper limbs of the U are reflected. A third and very long piece describes a figure-of-eight, the upper loop passing round the humerus, the lower surrounding the elbow. A circular band of strapping round the arm fixes the upper loop, while the lower is united with the loop of the vertical U. It is from this that the weight is suspended. The final appearance of the appliance is shown in fig. 60.

A pad of wool should be placed in the axilla to force the upper fragment slightly outwards. The forearm is supported by a sling. At night the weight is supported or removed, to be replaced in the morning.

When the dressing needs replacement, it is sufficient to remove the immobilising splints without interfering with the extension; carried out in this way, dressing is painless, if the patient is seated—that is, if extension is active.

The initial weight used should be 500 grammes, gradually increased to 1,200 grammes.

The simplicity of this appliance should not deter one from using it: the radiographs reproduced here (figs. 61 and 62) show a perfect reduction effected by it. The only disadvantage is that it cannot be used for cases that are obliged to remain in bed; in such cases it would be satisfactory merely to exert a horizontal pull, using the bar of a chair or any other similar arrangement as a pulley, but a suspension appliance such as will be described later is preferable.

When the formation of callus begins, after thirty to forty days, the wounds are usually reduced in size

and require dressing only at long intervals; at this stage I replace the extension by a plaster trough, including a cap moulded on the shoulder (fig. 51), but I have occasionally retained the extension appliance until complete cure was effected.

(ii) *When there is an interfragmentary loss of bone caused by the missile and cleared out by esquillectomy,*

FIG. 61.—Fracture of the humerus caused by a bullet, with punctiform cutaneous wounds; before continuous extension was applied.

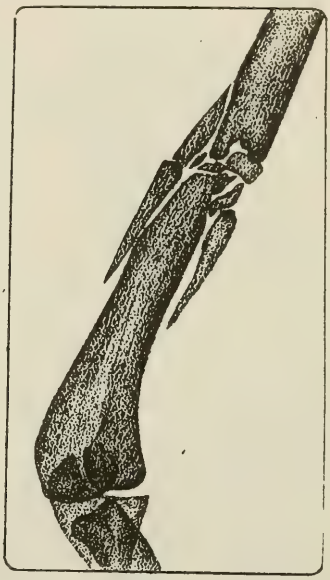


FIG. 62.—Result of continuous extension by simple application of a weight to the elbow (figure-of-eight arrangement of strapping). This radiograph was taken eight days after that in fig. 61.

continuous extension is unnecessary; reduction consists in immobilising in good position, for which plaster is sufficient: simple traction exerted on the plaster while it is drying brings the fragments into line, without the possibility of anything becoming interposed between them.

If the wound is not too large and runs an aseptic

course, a fenestrated plaster bandage may be applied, similar to that described on p. 394. As a rule, however, the wound in the soft parts is extensive and requires for its care comparative freedom of the arm, while it is better also that regular exposure to the air and sun should be possible.

After many experiments with interrupted plasters, I have abandoned these in favour of an appliance that has given me consistently good results for the last six months.*

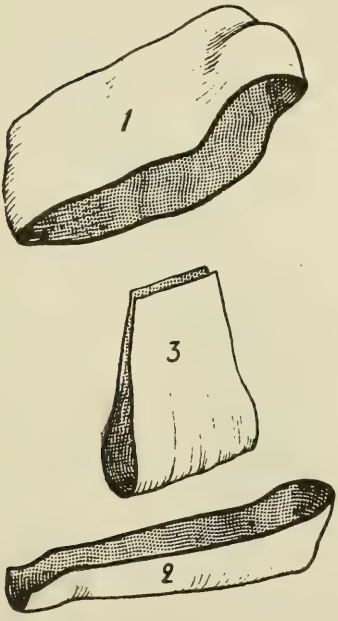



FIG. 63.

Two plaster bandages and three tarlatan splints each consisting of twelve thicknesses are prepared; one of these is passed round the chest and closely applied to the prominence of the shoulder (an essential point); another is used as a trough for the forearm, passing behind the elbow and a variable distance up the humerus; the third is used as a sling supporting the forearm splint (fig. 63).

Sometimes before and during the fitting of the appliance it will be found well to apply continuous extension to the elbow by means of a weight and a figure-of-eight-shaped collar, described on p. 421.

A large quantity of rather thin plaster paste is prepared, and the first step is to apply the large support

* Since this was written (June 1916) I have more and more generally used a simple external trough for the arm, dressing the wound at long intervals. The results have been excellent. On the other hand, I have seen in use the appliance of Alquier described above, and I think it is preferable to the plaster described here.

obliquely across the chest, moulding it well to the contours by well-placed depressions, and passing it over the shoulder. The slight final adjustments required for exact adaptation should not be hurried (hence the necessity for a thin paste). The trough for the forearm is then applied, the elbow being flexed and the hand pronated, with the thumb directed upwards. The edge of the splint should go as far as possible up the posterior aspect of the elbow, and the latter should be firmly surrounded by it. The sling is then adjusted in a good position and fixed by a safety pin.

When this has been done and the position of the arm has been verified and the fragments of the humerus have been found to be well in line, the three parts of the appliance are united with plaster bandages. When all is complete, only a half to two-thirds of the arm is exposed, and the two articular ends of the humerus are absolutely fixed (fig. 64).

FIG. 64.

This appliance is extremely convenient, and if well constructed, gives perfect results. After early subperiosteal esquillectomy, union generally occurs at the end of six weeks, and the appliance can be kept in place for the whole of this time.

For patients obliged to remain in bed, a suspension

appliance is the best. Continuous horizontal extension is first applied in line with the long axis of the arm by a weight of 1,200 or 1,500 grammes; the arm is then suspended by two triangular bandages wide

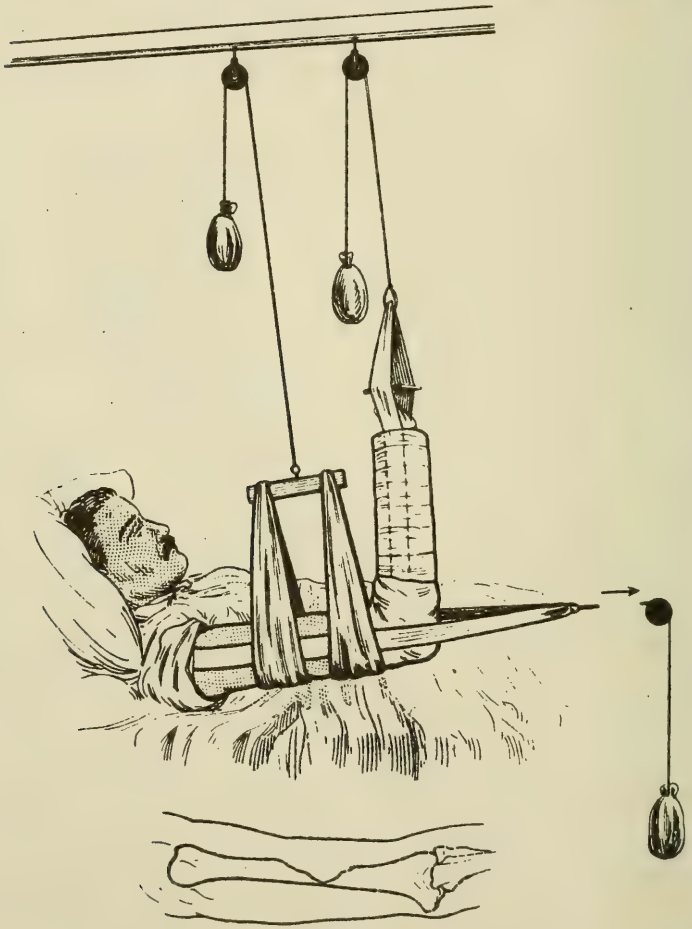


FIG. 65.*

enough to support the fragments well; these two bandage-supports are fixed to a small piece of wood

* For the sake of clearness, the bandage slings have been represented as rather narrow.

suspended from a pulley by a cord carrying the weight necessary to counterbalance the arm (usually 2 kilograms); the forearm, bandaged firmly over cotton wool, is suspended from a second pulley (see fig. 65).

6. TREATMENT OF CASES SEEN AT A LATE STAGE OR ALREADY UNDER TREATMENT.—Five possibilities should be considered:

(*a*) *A case progresses well after no operation or after an inadequate one.*—The wound, for instance, dates from five or six days previously, and the dangerous period has passed; there is no suppuration and no swelling. Such a case is very unusual. If no foreign body can be detected by X-rays within or near the bone, it is sufficient to employ continuous extension by the methods explained above (traction applied above the elbow through adhesive strapping).

FIG. 66. — Large-splintered fracture of the humerus. Total sub-periosteal esquillectomy was performed during the second day.

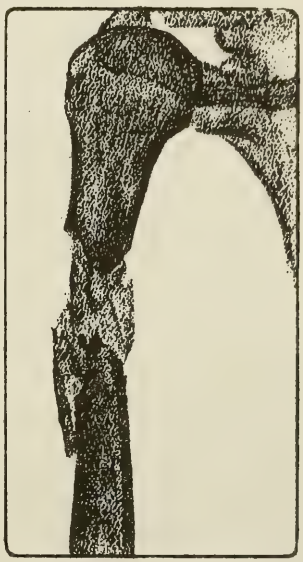


FIG. 67.—Result after two months of continuous extension by weights applied to the elbow; there was no pyrexia.

The course will be that of a bullet-fracture with punctiform skin orifices, *i.e.* that of a simple fracture.

If a foreign body is present, the steps to be taken depend upon its situation. If it is intra-osseous, exploratory sub-periosteal esquillectomy should be undertaken in order to remove it: delayed sepsis is, in fact, very probable, and its development should be prevented; removal, too, is easy in this early stage, whereas it is very difficult when it necessitates penetrating to the centre of a more or less recent callus.

If the missile is outside, but near the bone, the surgeon may either wait for the development of a small abscess which commonly forms, before removing it, or, after localisation, may remove it at once; this latter course, in my opinion, is decidedly preferable.

(*b*) *A fracture, after an inadequate operation, becomes subsequently profoundly septic.*—After X-ray examination, and localisation of the foreign body, if one is present, sub-periosteal esquillectomy and drainage should be carried out as early as possible; this is conducted exactly in the same way as the operation in the early stage. Eight to ten days after the operation, the condition of the fracture should be determined by a radiograph. If the wound is suppurating, or any débris remains overlooked, it should be removed, and subsequent clinical asepsis will usually be assured in eight to fifteen days. The fracture will unite normally without the tracking of pus to points remote from the wound, and without muscular sclerosis. Sometimes, however, after three or four weeks, superficial healing will apparently be arrested or a little pus will appear; this leads to the conclusion that there is slight osteitis of one end of the shaft, the marrow of which had been infected. After confirmation by X-rays, it will usually be easy with forceps to find a small and still adherent inflamed sequestrum, the removal of which will immediately

abolish these complications (see figs 28, 29, and 30, pp. 338 339 ).

Union usually occupies a month and a half, and complete cutaneous healing two months.

(*c*) *A case is seen at a late stage* (*after a month*) *suppurating more or less freely.*—The advisability of an operation on the bone is *very doubtful* ; osteomyelitis has seriously affected the region of the fracture, which should be interfered with as little as possible ; abscesses should be incised, and the wound drained, but only completely free splinters should be removed.

Esquillectomy on the lines advocated above would very possibly give rise to acute septic phenomena, and would injure the region without completely clearing it. It is better to refrain, immobilise, drain, and wait, meanwhile expecting a sinus to form.

(*d*) *A case is seen with a sinus.*—Instead of blind exploration with the probe, an X-ray examination from two aspects should be made to determine the cause of the sinus ; sometimes it will be a foreign body which must be extracted, more often it is a patch of superficial osteitis with a peripheral cavity partially enclosing a small sequestrum. A central cavity of variable size is almost always found ; the sides of this must be widely cut away, the edges bevelled, and the interior displayed as completely as possible, after removal of sequestra, if any are present. With this in view, the bone should preferably be approached from its outer aspect, not forgetting the presence of the radial nerve in the lower third of the arm.

(*e*) *A case is seen with pseudarthrosis.*—There should be no confusion between pseudarthroses and extensive losses of bone deliberately produced in a case of extensive crushing of the bone, when, the nerves and vessels being intact, it has been desired to avoid amputation.

The term pseudarthrosis is only applied if union fails to occur between fragments reasonably close

together. When a great length of bone has been lost, union is impossible; conditions are unfavourable for grafting, and it is better, at least temporarily, to fit a prosthetic appliance.

Pseudarthroses, on the other hand, should be treated by immediate operation; it is in no way necessary to wait for complete superficial healing of the wound before uniting the bone. It has seemed to me that the operation is more successful when the bones are infected and osteitic than when they are atrophied, worn away, and devitalised. I believe it is well, when possible, to send the patient for a preliminary stay at the seaside, or to treat him by sunlight, in order to strengthen the musculature, restore tone to the skeleton, and disinfect the tissues. The time employed in this physio-therapeutic cure is not lost, and it is largely to this that I attribute my habitual success in treating pseudarthroses of the humerus.

I believe that, from the operative point of view, osteosynthesis is preferable to grafting. Gunshot wounds are very bad media for a bone-graft; failures have been and will be numerous: on the contrary, osteosynthesis by Lambotte's plate or by wiring gives perfect results in the humerus.

When the operation has been decided on, the region of the fracture is very widely exposed by a long incision external to the vessels and nerves. The ends of the bone are freed with the rugine for a considerable distance in each direction, and every effort must be made to preserve as extensive a sheath of periosteum as possible; these extremities are resected to a sufficient extent to leave them symmetrical and consisting of healthy bone; the ideal is to find a normal medullary canal on section. All the interfragmentary fibrous tissue is excised, after which the extremities are fastened in position by one or two Lambotte plates and long screws.

The wound is left open and simply plugged. It

is undoubtedly possible in certain cases to sew up the incision again, and effect a cure by first intention. But in addition to these fortunate cases, there are many serious failures—suppuration, separation of the bones, recurrence of osteitis and a return to the condition of pseudarthrosis. If the wound is left open, no risks are run; progress is aseptic, and dressing is required only at infrequent intervals. I apply a plaster trough and leave the dressing in place as long as possible; at the end of seven or eight weeks the plates may easily be removed when union has begun.

### IV. Supra-condylar Fracture of the Elbow

1. Anatomical Features.—These common fractures occur immediately above the lower epiphysis of the humerus. They are usually comminuted; frequently one of the fragments of the shaft tapers gradually to a pronounced point, which is directed forwards in the case of the lower fragment, and backwards if it forms part of the upper.

There are often fissures running towards the joint; these sometimes end close to it without splitting the epiphysis; more frequently they reach the cartilage. If the injury is very violent, the fracture distinctly involves the joint, the humeral condyles are broken and the cartilage is shattered; there is, in fact, a condition constituting a definitely articular fracture.

There are sometimes associated nervous lesions, usually of the ulnar.

2. Physiological Features.—There is, as a rule, no displacement; the lower fragment inclines slightly forwards, and sometimes this is all; it is, however, serious, since, owing to this anterior inclination, union is difficult and the fracture is liable to pseudarthrosis.

There is often also separation of the lower fragment due to the weight of the limb, which carries the forearm and elbow either outwards or inwards.

3. Course.—The characteristic feature of this fracture is the presence of fissures running down towards the joint. They are unimportant if the fracture remains aseptic, since their repair and disappearance then follow very rapidly; if, however, there is any infection, it will invariably extend to the joint, and osteomyelitis in the region of the fracture is soon complicated by arthritis, at first serous and later suppurative.

Fig. 68.—Radiograph of a case which had suppurated for eight months without operation; numerous sequestra were eliminated spontaneously. The elbow was ankylosed in extension.

If the fracture has not been cleaned, and the infection is not virulent, a paradoxical development may be observed: the arthritis ends in ankylosis, and the fracture, failing to unite, ends in pseudarthrosis. I have examined three cases in which this curious result has been observed; it was favourable in one case, poor in another, and deplorable in the third (fig. 68).

But more often infection of the joint develops in a serious way, and necessitates secondary resection, if not amputation. Resection may give a good result, if it is kept strictly sub-periosteal and if the injuries do not extend too far up the limb; sometimes, however, some inches of the shaft are destroyed, and resection, though necessary, leaves a flail-elbow.

4. Indications for early Treatment and details of Technique.—The only means of avoiding the serious early and troublesome later developments enumerated above (severe articular infection, supra-

epiphyseal pseudarthrosis) is to perform early complete sub-periosteal esquillectomy which will permit exploration of the fracture and an aseptic subsequent course.

All other operations are uncertain in their results and leave the joint in danger.

*Method of approach.*—The best method of exposing the region widely is to make a free incision posteriorly

FIG. 69.—Supra-epiphyseal fracture of the elbow; joint intact.

FIG. 70.—Radiograph after early sub-periosteal esquillectomy; asepsis resulted. Case evacuated in satisfactory condition in fifteen days (June 1915).

in the median line through the triceps. Two retractors enable the surgeon to inspect the fracture and act as may be necessary: all fragments of bone are removed and every effort is made to preserve as much periosteum as possible. When the region has been cleaned, it will sometimes be well to trim the two extremities of the shaft with a saw, in order to produce even surfaces in the region of which aseptic development will be more easy. If there is a splinter-

like point, it should not be sawn away, but the rest of the circumference should be an even section.

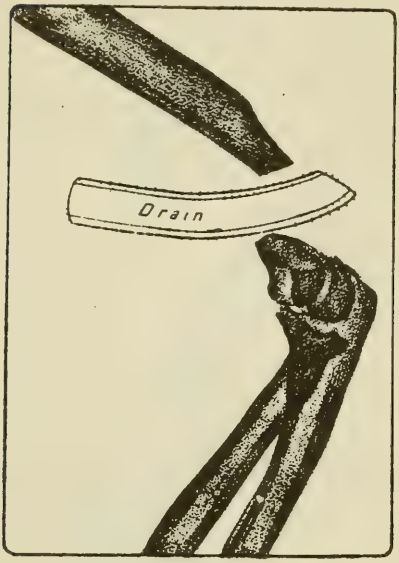



FIG. 71.—Supra-articular fracture of the humerus by a shell-fragment, September 29th, 1915. Total sub-periosteal esquillectomy performed on the following day with trimming of the extremities with a saw. The radiograph reproduced above was taken ten days afterwards. On December 1st the plaster was removed and the wound found to be completely healed without sinuses, and a radiograph showed an anterior periosteal callus uniting the fragments perfectly. Flexion of the elbow was limited by the projection of this block of ossification, but flexion to beyond a right angle was possible, and extension to about 160°.

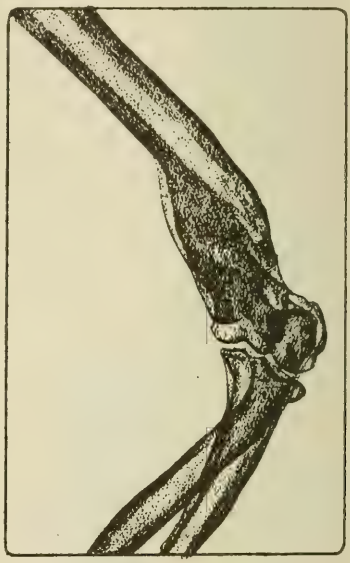


FIG. 72.—Radiograph after six months: flexion possible to considerably more than a right angle; full extension; muscular action perfect; slight torsion.

If deep fissures are found, and it is probable that they extend to the joint, they may be disregarded if the operation is being performed in an early stage. If infection is already evident, its extension to the joint may still be avoided, but is very much to be feared. It is not necessary, however, unless the injury to bone is very

extensive, to perform resection of the joint at once, since a favourable course is still possible. If the opposite is the case, there should be no hesitation in performing this operation, but the periosteum, capsule, and muscular insertions must be preserved carefully. By an "exaggerated" sub-periosteal operation I was able, in a case of this kind, to obtain regeneration of the shaft and epiphysis to the extent of about 4½ in., with very satisfactory functional play of the elbow.

The operation of esquillectomy and trimming with the saw being completed, fixation should be effected by a posterior plaster trough with the elbow fully flexed: the best reduction can be obtained in this position. I have never employed any other plaster but the posterior form, and I find it decidedly preferable to interrupted appliances for strict immobilisation of a fracture the course of which is, as a rule, very simple after careful esquillectomy. The plaster is removed for each dressing, which may be delayed for an average of at least seven or eight days.

Union occurs with considerable rapidity, although the periosteum of this region is not very fertile; it has generally been effected in my own cases within a month or two.

5. TREATMENT OF CASES SEEN AT A LATER STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case is seen progressing well.*—Rigorous fixation in the flexed position is alone required; the meaning of the words "progressing well" should, however, be well understood; this means to say that the wound is absolutely aseptic, without the slightest discharge. If there is any suppuration, secondary arthritis (of which no signs sometimes appear until the tenth or twelfth day) is always to be feared, in spite of favourable appearances, and immediate total esquillectomy should be performed.

(*b*) *A case is seen with a septic wound.*—Immediate total sub-periosteal esquillectomy is necessary; there

is no other means of cleaning the region of the fracture and preventing involvement of the joint. If arthritis is present, and there are markedly infected fissures, strictly sub-periosteal resection of the whole humeral epiphysis should be performed. I have carried out this late secondary resection on three occasions in cases evacuated from the front in a seriously septic condition. Very complete periosteal regeneration was obtained (see figs. 42, 43, 44, 45 of Part I) and the results have been satisfactory: the arm was firm, and a good degree of the normal range of voluntary movement was regained. As a precautionary measure, I applied a small copper splint with rigid springs, to give more fixity to the joint.

(*c*) *A case is seen with fistulous osteitis.*—Unless the case is one of superficial osteitis, easily curable by a small operation, resection of the elbow is frequently necessary.

(*d*) *A case is seen with pseudarthrosis.*—If there is no infection, an incision may be made along the median line through the triceps, and the bones united by a Lambotte plate or metal wire, after excision of the interfragmentary scar-tissue. I have never had occasion to do this.

## CHAPTER XIII

### FRACTURES OF THE FOREARM

THE treatment of fractures of the forearm cannot give good results unless we take into account certain new physiological factors which regulate the mechanical conditions under which the forearm and hand perform their functions, since these factors ought to direct the treatment before and during the formation of the callus.

The treatment of fractures undoubtedly demands a clear comprehension of local physiological conditions in any region in order to attain its object, which is the most perfect functional recovery possible for the bone lever concerned; but, if necessary, an enlightened empiricism can take the place of physiological theory.

In the forearm this is not so; the forearm has a special function, the integrity of which is necessary for perfect movement of the hand. The surgeon who does not understand its physiology exactly, that is, who does not understand the precise mechanism of pronation and supination, will often be responsible for functional disasters which a better-informed man will easily avoid.

I consider this is so important that I shall depart from the usual plan of this little volume and first explain these fundamental physiological views: they are still little known, having only recently been de-

finitely stated.* All this knowledge is owing to Destot, who has constructed an original theory of the functions of supination and pronation based upon radiographic analysis; the problem is thus definitely solved, notably from the surgical point of view.

The following points must be clearly understood before the surgeon can treat a fracture of the forearm suitably:

(1) Pronation and supination are exclusively effected by the radius, which revolves round the ulna, carrying the hand with it; the ulna only moves slightly in an antero-posterior direction.

(2) The axis of rotation of the forearm is oblique; it may be represented by a line connecting the head of the radius with the lower extremity of the ulna.

(3) The head of the radius revolves in a socket, while the distal end of the bone undergoes circumferential movement round the head of the ulna: the transformation of the movement at the proximal end (rotation on its own axis) to that at the distal end (circumferential rotation—*i.e.* round an external axis) is caused by the outward curve of the radius, and by the existence of a cervico-diaphysial angle. If the shaft were straight, the movement would remain axial and consist in simple rotation on that axis.

(4) During this movement, the width of the interosseous space remains fixed, whatever be the position of the two bones. In radiographs the interosseous space appears wider in pronation than in supination, but this is an error of projection: the width of the space does not vary if the plates exposed are placed parallel to the plane of the dorsal aspect of the wrist.

(5) The lower part of the ulna is a sort of pivot round which the distal extremity of the radius moves:

* It has been my first object in this to be as clear as possible, referring the reader for greater accuracy and fulness to the recent treatise on fractures in which Tanton, dealing with peace-time fractures, gives a complete exposition of this difficult question, and of the work of Destot.

the latter is so constituted that it is always in the same degree of pronation or supination as the upper extremity.

(6) The upper and lower radio-ulnar joints are, so to speak, lateral hinges, which only maintain their connection if the relative length of the two bones is maintained constant: these joints are connected for a unique purpose, and equality in length of the bones is a necessary factor for their normal functioning.

It follows from these laws of Destot that four fundamental conditions control the physiology of the forearm:

Preservation of the outward curve of the radius, permitting the movement of circumduction in the lower extremity;

Preservation of the relation between corresponding points in the head and the distal extremity of the radius;

Equality in length of the bones;

Preservation of the axis of rotation of the forearm.

It will be understood from this to what objects the treatment of fractures of the forearm should be directed.

Three varieties of fractures of the forearm must be studied:

Fracture of both bones;

Fracture of the radius only;

Fracture of the ulna only.

## I. FRACTURES OF BOTH BONES OF THE FOREARM

From the point of view of treatment three different types exist:

Fractures just below the elbow joint;

Fractures of the shafts proper;

Fractures just above the wrist.

### A. Fractures just below the Elbow Joint.

1. Anatomical Features.—These fractures are

usually caused by great violence and are comminuted; the radius is broken in the region of the neck, and the ulna below the sigmoid cavity, but there is frequently an internal splinterlike projection, and the bicipital tuberosity remains as a part of the upper fragment. In the more simple type there are no radiating fissures, but the injury is frequently more complex; in the radius at least, the cartilage is split, and the fracture is therefore intra-articular. Fissures involving the joint are less usually seen in the ulna, the coronoid process and olecranon being very resistant, but long fissures frequently travel down the shaft of the ulna.

The posterior branch of the radial nerve may be injured close to the neck of the radius.

2. Physiological Features.—There is little displacement of the fragments of the ulna; those of the radius, however, exhibit it constantly: the head and neck are displaced by the biceps, which remains, at least in part, inserted into the upper fragment in which it produces a combined movement of flexion and supination: hence, the head of the radius swings forward and turns on its axis, while the shaft, under the action of the pronators, assumes a position of full pronation.

3. Course.—As a result of muscular action, even in the most favourable cases when infection does not necessitate early intervention, union of the radius is difficult, and even if it occurs, the two fragments concerned are generally displaced (*i.e.* rotated) in opposite directions.

In fact, there is at least a tendency to radial pseudarthrosis, and a risk of losing the power of supination and pronation.

On the other hand, particularly in mild cases, when the bicipital tuberosity has been smashed up and the biceps consequently put out of action, a radio-ulnar synostosis may occur, which prevents the movements of pronation and supination. These results, however,

are rare, for the sufficient reason that this highly splintered region is usually seriously infected. The infection extends to the joint along the fissures, or simply as a result of contiguity, and if early acute septic phenomena have not occurred, marked suppurative arthritis soon develops; the upper fragment of the radius undergoes rapid necrosis, and formidable complications ensue. Unless resection is performed, arthritis often ultimately necessitates amputation.

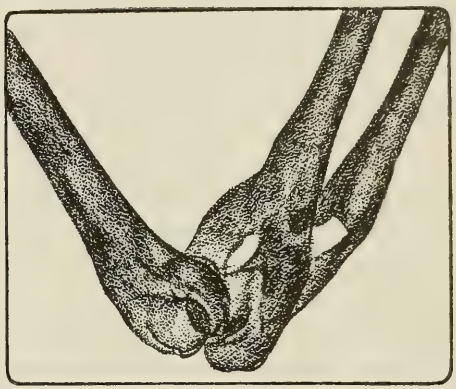


FIG. 73.—Radiograph showing displacement of fragments in a sub-epiphyseal fracture of the radius and ulna by a shell-fragment. Operation twelve hours later, and cure effected, but with radio-ulnar synostosis. Flexion and extension of the forearm are normal. Pronation and supination are not possible. The result is remarkable.

Further, pus rapidly forms in the region of the ulnar fracture and abscesses spread among the flexors and damage them seriously (see p. 448). The flexors undergo necrosis, and there is marked interference with finger movements. I have seen a case at a medical board with ankylosis of the wrist secondary to a sub-articular fracture of the forearm; infection had passed along the flexors and produced radio-carpal arthritis.

In the rare cases which run a favourable course, ankylosis generally occurs, with a persistent osteitis of the radius; the power of pronation and supination is permanently lost.

Sometimes sub-articular radial pseudarthrosis may occur; contrary, however, to what might naturally be supposed, there is no functional improvement.

In brief, suppurative arthritis, ankylosis, pseud-arthrosis, radio-ulnar synostosis, and contraction of the flexors, are the dangers in sub-epiphyseal fractures of the bones of the forearm.

4. Indications for early Treatment.—The only means of avoiding arthritis of the elbow joint consists in completely cleaning the fracture area as early as possible. For this purpose, whenever circumstances permit, there should be a previous examination by X-rays or by a radiograph.

If the fracture is limited and no fissures are visible, anatomical conservation may be attempted, that is to say, only sub-periosteal esquillectomy is performed. The osteogenetic power of periosteum near the epiphysis is, however, not very great; moreover, the neck of the radius is displaced, with the fractured surface pointing upwards, and under these conditions a good anatomical result is difficult to obtain. When union occurs, the cervico-diaphysial curvature of the radius, which has been discussed in connection with the physiology of the forearm, is generally abolished, and the power of pronation and supination is lost.

Owing to these bad local conditions, when fissures extend to the epiphysis, when the damage is considerable, and particularly when operation is not distinctly early, I believe that sub-periostial resection of the elbow is preferable. More extensive lesions are always found in the joint than were expected; moreover, resection has the advantage of ensuring complete prevention of serious infective developments, and of enabling repair to take place under aseptic conditions. I have obtained a very good functional result in two cases of this kind.

If, on the other hand, the fracture involves the shaft more than the immediate vicinity of the epiphysis, I believe simple esquillectomy to be preferable.

It is on account of these different possibilities that a preliminary radiograph is necessary.

*Technique.*—In all cases, exploration of the region should be begun by an incision of sufficient length to expose it thoroughly. A posterior median incision, slightly external to the ulnar crest, is preferable: by this means the condition of the radius and ulna may be easily investigated. Clearance with the rugine may be immediately begun on the ulna. Injury to the flexors should be avoided as far as possible. If resection appears necessary, it should be total, that is, the articular ends of all three bones should be resected: the humerus is sawn through below the epitrochlear-epicondylar line, only the cartilaginous surface being removed. I explained in Part I, p. 154, why these rules should be followed: the mutual adaptation of the bones is better, and the functional results are more perfect. I shall not discuss this further.

5. TREATMENT OF CASES FIRST SEEN AT A LATE STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case unoperated upon is doing well.*—If no foreign body is present, intervention is not required, but merely rigorous immobilisation, the elbow being flexed to an acute angle in order to approximate the two fragments of the radius. I have seen remarkably good functional results follow this simple treatment.

If a foreign body is present, its immediate removal is preferable to delay.

(*b*) *A case is seen with a septic wound.*—If the infection is confined to the shaft, sub-periosteal esquillectomy through a posterior incision is sufficient.

If, on the contrary, the fracture implicates the epiphyseal ends at all, or if there is the slightest sign of involvement of the joint, sub-periosteal resection, extensive as far as the bones of the forearm are concerned, but limited in the case of the humerus, should be performed at once.

(*c*) *A case is seen with a sinus.*—After X-ray examination, and according to the nature of the lesion, the following steps should be taken:

Removal of a sequestrum or splinter, if the bony lesion is limited.

Resection, if injury to the shaft is not extensive, and if the joint is clinically involved.

(*d*) *A case is seen with a pseudarthrosis of the radius.*—It will be sufficient, as a rule, to remove the upper fragment, that is, the head of the radius from behind, to obtain great functional improvement, provided that the fragment does not include much of the shaft. It is necessary for pronation and supination that the radius should be fixed at its upper extremity; the annular ligament must, in fact, support all or part of the neck of the radius.

**B. Fractures of the Shafts.**

1. ANATOMICAL FEATURES.—The fragments are usually small, and not markedly displaced, except in bullet wounds showing explosive effects; the latter are very frequent, and, owing to their variety, are impossible to describe. It is exceptional to see the large-fragment type, but the cuneiform fragment is often seen in both bones (fig. 75), or the butterfly-wing fracture.

The injuries are situated at the same level in the two bones or at different levels, according to the angle of incidence of the projectile.

An important fact is that the extent of the fracture is not usually the same in the two bones.

There is, as a rule, little longitudinal displacement; on the other hand, the force of impact almost always causes antero-posterior displacement with postero-lateral angulation.

According to its situation, the fracture is either buried beneath the flexor muscles, or, on the other hand, superficially situated in the tendinous part of the forearm. This distinction is important.

Associated injury to nerves is frequent.

2. PHYSIOLOGICAL FEATURES.—These are of the

first importance. In the first place, the fracture destroys the equilibrium of the muscular forces of pronation and supination : nothing can prevent the upper fragment from being completely and permanently supinated by the contraction of the biceps, the supinator *par excellence*. On the other hand, the lower fragment is given over to the unrestricted

FIG. 74.—Comminuted fracture.

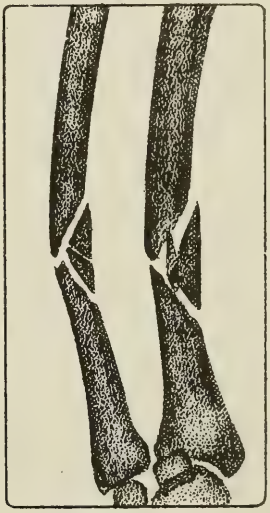


FIG. 75.—Cuneiform fracture.

pronating forces exerted by the pronator teres and particularly the pronator quadratus.

The two fragments consequently rotate on their long axes in opposite directions ; in the words of Destot, " *ils se décalent* " (disconnection, or counter-rotation, occurs), and if this is not corrected, if the two fragments unite in the position imposed by the antagonistic muscular forces acting on them, the bones unite, with the muscles completely relaxed : pronation and supination become permanently impossible.

Moreover, owing to the momentum of the missile, the fragments of the bones are frequently displaced

laterally. If the displacement occurs inwards, angulation is produced with the apex to the inner side of the forearm. The effect of this is to abolish the external radial curvature, an essential factor, as we have seen, in the production of the rotatory movement which is the basis of transition from pronation to supination.

This, therefore, is a further danger which threatens the essential function of the forearm.

The other lateral displacements are less serious, but always diminish the possible range of pronation and supination.

There are further physiological aspects to be considered in fractures of the forearm, which will be studied in connection with the course of the cases.

3. COURSE.—Apart from the very serious fractures from bullets causing explosive effects in the soft parts, these fractures are less frequently fatal than fractures of the shafts of other bones. Apart from cases of gas gangrene, which are always possible if early disinfection of the fracture has not been carried out, death does not result from fractures of the radius and ulna : the bones are too superficially placed and too accessible to permit the development of the most serious phenomena of sepsis. But although death may not result from a fracture of the forearm, amputation of the arm may be necessitated by a fracture of this kind, and, above all, loss of use of the hand and fingers may very easily result from it.

In fact, though less serious than elsewhere, since the formation of a closed cavity is less likely to occur in this region, the development of septic conditions is equally constant.

Suppuration causes local changes, the functional results of which are deplorable. There are two types, according as the fracture is situated in the muscular or the tendinous part of the forearm.

(*a*) *In Fractures in the muscular part of the Forearm.*—Tracks of pus separate the muscles, insinuating

themselves between them. If this condition is treated by repeated and prolonged drainage, damage to and loss of substance of the flexor muscles result from contact with pus and drainage tubes, and even from the operations required; these lesions ultimately result in sclerosed muscles and contracting scars.

During the active stage of infection this manifests itself by flexion of the two last phalanges upon the palm of the hand. This condition is very painful, and the slightest movement of the fingers causes considerable suffering; moreover, unless it is corrected at an early stage, muscular scarring will render it permanent and the fingers will remain flexed. When this contracture is studied, it will be seen that there is no possibility of straightening the fingers while the wrist is extended. If, on the other hand, flexion of the wrist is carried out, extension of the fingers is possible. There is therefore a syndrome of cicatricial shortening of the flexors identical with that caused by ischæmic paralysis, and this, being caused by a loss of substance and cicatrisation, is a permanent lesion. It can only be remedied by shortening the bones, which are already diminished in length by the fracture; this operation, in a forearm infected for a long period, is done under very unfavourable conditions, and its functional result remains doubtful.

This muscular complication in high fractures of the shafts is therefore much to be feared, which amounts to saying that the infection causing it should be anticipated.

(*b*) *In Fractures in the tendinous part of the Forearm.*—The infected fractured region is in immediate contact with the tendons and their sheaths. Further, it frequently happens that certain tendons have been injured directly by the projectile; they are severed or lacerated, but repair is possible if the injury remains aseptic; they necrose and are eliminated if it suppurates. After a long period of suppuration, their

ends adhere to the skin, become involved in a block of scar tissue in such a way that when anatomical cure is obtained, functional recovery has become impossible, and the use of the limb is permanently impaired.

Wherever, in fact, the fracture may be situated, the consequences of infection are deplorable from the functional point of view.

This, however, is not all that may supervene in fractures as a result of infection; sepsis also introduces a danger of pseudarthrosis, and in the following way. The gap between the fragments is usually wider in one bone than in the other; as fragments gradually undergo necrosis and are eliminated, there is a loss of bone substance in each case, but this gap is wider in one than in the other; hence a tendency to pseudarthrosis of one bone.

Add to this the serious disturbance caused by torsion in opposite directions, and the gravity of fractures of the forearm from the functional point of view will be understood.

Everything possible should therefore be done to prevent infection, to avoid pseudarthrosis, and to reduce the fracture suitably.

4. Indications for early Treatment.—The first necessity in this case as in all others is completely to prevent the development of septic conditions by thorough exposure of the affected region; permanent asepsis assured in this way will facilitate reduction and its maintenance.

It is further necessary to reduce the gaps between the fragments to the same dimensions in order to facilitate union, to correct torsion, to reduce lateral displacements, to keep lesions of the flexors under observation, and to repair injuries to tendons.

Complete recovery of the functions of the hand, to which treatment is mainly directed, is therefore a very difficult matter.

Emphasis is again laid on the fact that asepsis of the fracture is an essential condition.

For this reason complete sub-periosteal esquillectomy should be performed after an X-ray examination as early as possible.

I am aware that some surgeons regard it as useless because grave sepsis is uncommon, but I consider this argument worthless. The object of intervention is to *ensure in all cases as complete a preservation as possible of the movements of the hand, and of pronation and supination.* This object is worthy of considerable effort, and systematic intervention is the only means of attaining it. There is no other way of avoiding that fistulous callus-formation, which is sometimes obtained with difficulty after several months, leaving the forearm thin, scarred, and deformed, the hand flat, its muscles degenerated, and the fingers shrunken, weak, and clumsy.

5. Technique.—Esquillectomy is carried out, when choice is possible, by means of a median posterior incision if the fracture is situated high up; this incision should pass slightly outwards from the ulnar crest, and will often be sufficient. This will avoid the necessity of making a second incision over the radius, which would risk severance of the motor branches to the extensors.

In the middle of the forearm it is preferable to make two lateral incisions, each over the projecting part of the bone to be exposed.

As the fragments are usually small and not much displaced, some determination is necessary to perform adequate esquillectomy, that is to say, to remove each splinter by careful use of the rugine. The necessity of avoiding injury to the periosteum need scarcely be emphasised. Care must be taken to free the muscles from minute splinters which may be adherent to them. This practice will obviate a great deal of abscess formation in the later stages.

After clearance of both fractures, the width of the interfragmentary gaps should be compared, and these should be reduced to the same dimensions : the best instrument for this purpose is a Gigli saw. Precautions, however, should be taken to protect the periosteum,

Fig 76.

Fig. 77.

Fig. 78.

Fig. 76.—Radiograph after complete esquillectomy for fracture of both bones of the forearm by a rifle bullet with great explosive effects. The operation, performed on the fourth day, obviated the necessity of amputation in a case seriously affected by infection, due to multiple wounds, including a fracture of the tarsus.

Fig. 77.—Two months later. Approximation of the fragments. The two extremities of the radius are in process of periosteal fusion ; the fragments of the ulna are less widely separated than before, and the neighbouring periosteum is very active.

Fig. 78.—Two months later. Union is complete in the radius without a sinus. The ulna has not reunited, but this pseudarthrosis gives little trouble. The fingers are stiff, but no tendons have been destroyed. Resection of the radius, by equalising the interfragmentary gaps, would probably have effected union of both bones.

since it may otherwise be lacerated by the saw, and periosteal regeneration thereby jeopardised. After the operation, a dressing of aseptic gauze is applied to each wound. The forearm is immobilised in a position

of supination and semi-flexion. The best means of effecting this is a posterior plaster trough, with an aperture for the thumb, and enclosing the palm of the hand (fig. 87, p. 471).

If esquillectomy has been performed correctly, no difficulty will be experienced in reducing the fracture and maintaining reduction; for this reason, I consider continuous extension unnecessary.

After some days, when the wounds are healing normally, an

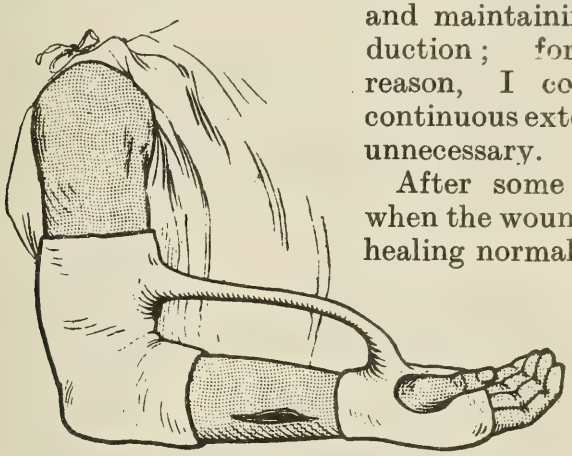


FIG. 79.—Interrupted plaster splint for fracture of both bones during consolidation.

interrupted plaster splint may be substituted to facilitate dressing, but it is better not to apply this early, unless the condition of the wound requires it.

This plaster includes :

(*a*) An upper section, enclosing the lower part of the arm, the elbow, and the upper part of the forearm ;

(*b*) A lower section, enclosing the lower part of the forearm and the hand ;

(*c*) A loop, or two loops, which should not consist of metal. I now invariably make them with a few layers of plaster bandage, held in position by an assistant until they have set ; around them a few more turns of plaster bandage are wound for the sake of strength and compactness.

If extension should appear necessary, it should be

effected by fitting a slide or screw connection to the plaster, such as is illustrated on p. 375 No appliances are more easily constructed than these.

Sometimes it will be well, when the fracture is exactly in the middle of the forearm, to support the dorsal aspect by means of a plaster rest 1 inch in width, connecting the two circular sections. The tendency to posterior sagging of the four fragments concerned may be avoided in this way.

In certain cases, continuous extension by a suspension apparatus may be employed with advantage. The sling should consist of strips fixed on a metal frame, as shown in fig. 80. Extension is applied to the lower third of the forearm. Counter-extension may, but need not necessarily, be applied to the elbow.

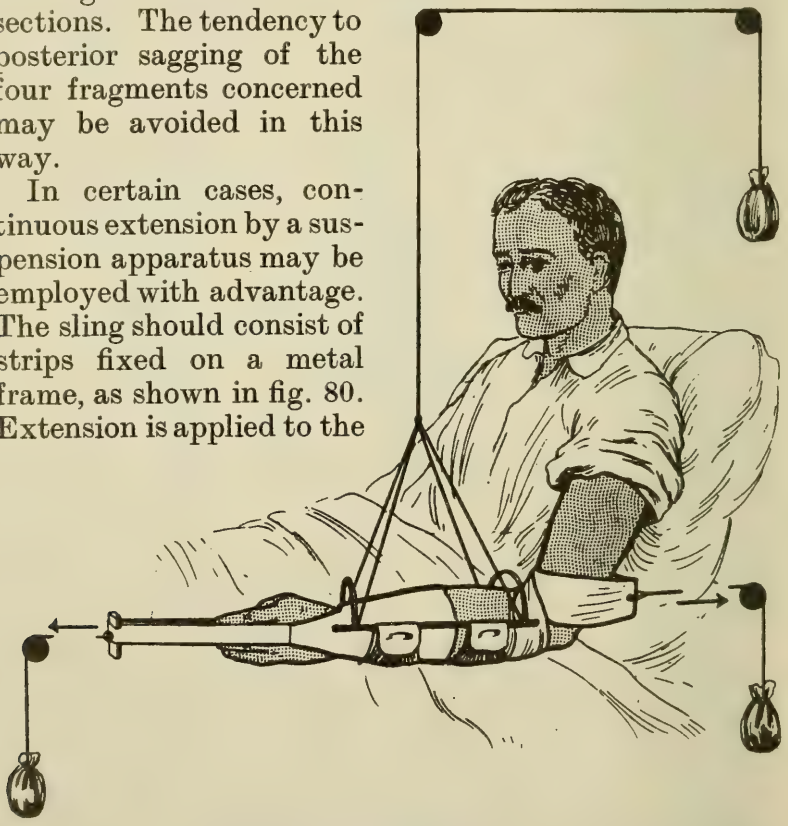


FIG. 80.—Immobilisation and continuous extension in a suspension apparatus. Extension by a weight of 800 grammes, counter-extension 800 grammes, counterpoising weight 1,200 grammes. For the sake of clearness, the hand is shown in semi-pronation, and not in supination.

A simple bracket fitted with two pulleys is used to suspend the sling. This is an excellent appliance.

As a rule, when esquillectomy has been performed promptly, these fractures get well without difficulty in forty or fifty days, leaving scarcely any trace of the injury, unless there has been irreparable damage to muscle.

In addition to the simple cases which have been studied there are other more complicated ones :

Apart from associated nervous lesions, which should be treated at once whenever intervention is undertaken at a really early stage, any of the following complications already alluded to may occur, according to the position of the fracture :

(*a*) *In fractures high up*, painful contracture of the fingers, due to irritation of the flexors. This usually appears at a later stage, and does not occur if the wound remains aseptic.

When it does occur, and the existence of true contracture of the fingers is established, the wound is first examined, and continuous extension is applied to the fingers. For this purpose, a rigid prolongation, of wood, plaster, or metal, should be fixed to the plaster, fitted with a pulley over which passes a traction cord pulling on an india-rubber loop passed round the fingers. This has always enabled me to effect a slow straightening of the fingers ; the method is less painful, and undoubtedly more effective, than sudden straightening by force, which causes injury, and is therefore dangerous.

This complication requires early treatment and careful attention, for the contracture gradually becomes more marked, straightening becomes more and more difficult, and ultimately correction by operation is necessary, the result of which is always doubtful.

(*b*) *In wounds in the lower part of the forearm*, involving tendons, the problem presented is totally different.

If the injury to tendons is not extensive and is easy to repair, and if the wound is disinfected at an early stage, tendon suture should be performed at once with all the care which this delicate operation requires.

On the other hand, if the laceration of tendons is very extensive, as, for instance, in bullet wounds associated with explosive effects, and if there is no certainty of ultimately producing complete asepsis of the wound, it is better to postpone tendon suture for the time being, and merely as far as possible to prevent complications in the immediate neighbourhood of the fracture. There should even be no hesitation in excising any sections of tendon which are completely destroyed and would eventually be eliminated. This is a matter for surgical common sense which cannot be expressed in formulæ.

6. Treatment of cases seen at a late stage, or already under Treatment.—(*a*) *A case progressing well without operation.*—If there is no pyrexia and no suppuration, intervention is obviously not called for, and all that is necessary is fixation in good position (supination, with the hand flat), but continuous extension should be combined with this, and in such a case the looped plaster appliance should be replaced by one with sliding shafts, or with concentric cylinders kept apart by a spring. This fixation with extension should be continued for thirty to forty days. At the end of this time, it should be ascertained clinically and by X-rays whether union has occurred. If the bone is solid, cautious movements are begun; the limb is placed in the plaster again at certain hours and during the night for about twelve days. If the callus is soft, the limb should be carefully re-immobilised, since otherwise there is a danger of secondary curvature.

(*b*) *A case is seen in a septic condition.*—The region of the fracture must be completely cleaned at once;

as has already been said, sub-periosteal esquillectomy of both bones should be performed, the two inter-fragmentary gaps being reduced to equal dimensions. It is sometimes of advantage to smooth off the extremities with a saw, or at least to abolish marked irregularities, but in doing this, particular care should be taken with the periosteum, which should be kept well clear of the saw.

If tracks of pus are present, they should be widely exposed: the best method of preserving the muscles is to protect them from infection and from prolonged contact with pus. I cannot explain the lack of biological understanding in certain surgeons who permit sclerosis and atrophy of the muscles in order to avoid a cutaneous scar. It should therefore be remembered that the best means of avoiding extensive scars in these cases is to make a large incision in good time. If gangrenous fasciæ and necrosing tendons are exposed in this way, everything should be excised which is undergoing necrosis; it is no economy to leave in a wound tissues which must ultimately die.

It will be said that this requires experience, and this is true, as it is true of all surgery.

When the bony region has been surgically cleaned in this way, and the tracks of pus have been exposed, the wound should merely be plugged loosely with aseptic gauze, and the limb correctly immobilised while the sepsis diminishes. Suppuration quickly ceases, and the subsequent course is that of a fracture disinfected at an early stage. Occasionally, however, suppuration reappears to some extent after a time, and the edges of the wound become œdematous, but there is no constitutional disturbance. This is due to necrosis of a ring-shaped fragment at one or more of the bony extremities concerned; after gentle removal of these small and still adherent sequestra by means of forceps, suppuration ceases, and union is scarcely delayed by it. Union never fails to occur,

and speaking personally, I have never yet seen a pseudarthrosis of both bones of the forearm.*

During progress towards recovery, inflammatory contraction may develop, followed by cicatricial contraction of the flexors, causing the syndrome that has already been discussed.

This singularly troublesome deformity must be watched for and not permitted to develop or, above all, to become permanent.

I have already explained how it could be corrected by continuous extension of the fingers.

In the event of grave infection, amputation may become necessary; hitherto, I have always been able to avoid it by free esquillectomy.

(*c*) *A case heals with marked angulation or other vicious union.*—If union is recent, it is generally possible, under an anæsthetic, to rectify the position by hand.

On the other hand, if the callus is very resistant, the only resource is osteotomy, which should be performed at the original point of fracture.

There is often hesitation in performing osteotomy, because this is sometimes followed by a sudden and dangerous redevelopment of infection. In my own experience, there is nothing more easy than to avoid such bacterial recrudescence; it is merely necessary to leave the wound open, using no sutures, and plugging down to the bone surfaces.

With this method I have never yet seen osteotomies followed by serious infection.

Fixation of the hand in extreme pronation calls for the same operation. I have obtained good results from it.

(*d*) *A case is seen with radio-ulnar synostosis.*—This is unusual: up to the present I have only seen very

* Since writing this I have seen pseudarthrosis in a case which suppurated for a long period after inadequate esquillectomy and the elimination of several sequestra. Double osteosynthesis was necessary.

high radio-ulnar synostosis in the upper third of the forearm, the connection with one of the bones being very slight.

If the position is bad, as is usually the case, the hand being fixed in extreme pronation by counter-torsion, mere destruction of the synostosis will not restore normal movements. Moreover, it is a difficult operation, particularly in the upper part of the forearm, where the only possible approach to the synostosis, by a posterior incision, is complicated by the presence of the motor branches of the radial nerve.

FIG. 81.—Radio-ulnar synostosis. The ulnar lesion is inconsiderable, but the connection is twice as extensive as the radiograph indicates. This was broken down. It would have been simpler to perform osteotomy below the callus, and this would have given an equally good result.

The bone connection is always found to be much larger than it appeared in the radiograph.

In a case of this kind I have had great difficulty in attaining the desired result.

I therefore believe it preferable merely to correct the deformity by osteotomy and fixation by a Lambotte plate : I have obtained a very satisfactory result in this way.

(*e*) *A case is seen with a pseudarthrosis.*—This again is an unusual occurrence ; pseudarthrosis of both bones of the forearm is fortunately very exceptional, as this is a very troublesome condition. I have never seen it, and Nové-Josserand recently said that he had never operated on such a case. This is explained by the fact that pseudarthrosis is due to the impossibility of reducing the interfragmentary gap owing to the presence of the other bone in a healthy and therefore rigid condition.

Should it occur, the solution of the difficulty is double metal fixation, after suitable trimming; a double bone-graft is a very doubtful proceeding. The use of an external support slightly reduces the serious functional disorders caused by pseudarthroses, but it is only a makeshift.

**C. Fractures just above the Wrist.**

1. Anatomical Features.—These fractures are exceptional, as only one epiphysis is usually injured. They are characterised by comminution of the lower epiphyseal ends of the radius and ulna. Fissures pass upwards into the shaft, but in my experience the cartilage of the wrist-joint is usually intact and fissures into the joint do not occur.

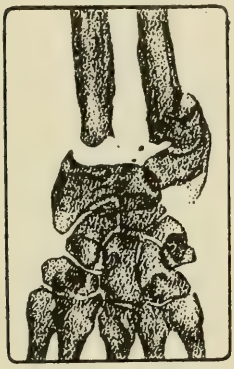


Fig. 82.—Epiphyseal radio-ulnar synostosis with pseudarthrosis of the radius, following extra-periosteal esquillectomy. Power of pronation and supination is lost, but the hand is well- and rigidly supported.

The injury is always more extensive in one bone than in the other; the radius, being more exposed, is almost always the more seriously injured.

The frequent association of serious tendon and nerve lesions should be noted.

2. Physiological Features.—There are few of importance, at least in the early stages: scarcely any displacement occurs, because there is little muscular action to effect it; counter-torsion due to the action of the pronator quadratus is possible, but is not constant.

From a general point of view, there is a prospect of serious interference with function (loss of pronation and supination, associated injuries to the median and ulnar nerves, and to tendons).

3. Course.—This fracture is extremely serious, unless immediate disinfection is practised. Infection develops readily in the cancellous tissue of the epiphyses, sometimes spreads to the carpus (even when fissures are not present), but in particular almost invariably extends along the tendons and their sheaths hence the phlegmanous suppuration which is only to often followed by amputation.

In those exceptional cases which progress well without esquillectomy, the orthopædic and functional result is generally deplorable ; the hand, through want of attention, becomes fixed in a vicious position (extreme pronation) ; further, owing to the unequal size of the two interfragmentary gaps, lateral deviation of the hand is produced, the latter being forced over on the side of the shorter bone by the longer. These are incurable deformities, of which lamentable examples may be seen in the Physiotherapy departments at the base.

I have never seen pseudarthrosis of both bones, but I have met with a curious case of radial pseudarthrosis compensated by radio-ulnar synostosis (fig. 82).

4. Indications for early Treatment.—There is only one: double sub-periosteal esquillectomy must be performed as quickly as possible, the two interfragmentary gaps being reduced to roughly the same dimensions, unless the loss of bone is more extensive in the ulna. Pseudarthrosis of the ulna low down interferes so little with function that it is practically negligible ; it is therefore sufficient to ensure union of the radius.

Sometimes the clearance will end by leaving only a thin layer of cancellous tissue on the upper surface of the radio-carpal cartilage. This need cause no alarm ; if no fissures are present, and, in particular, no infection, an uneventful recovery will follow, without reaction on the joint.

In operating on the radius, the medullary canal

should be examined carefully in all cases; on several occasions I have found fragments of the coat-sleeve firmly ground into the bone that could not be detached without energetic curetting. I need not insist on the disadvantages of leaving such structures in the bone.

*Technique.*—The esquillectomy is effected through two lateral incisions, situated, if possible, on the dorsal aspect. In the case of the radius, this possesses the advantage of avoiding the radial artery, and further, it is easier to preserve intact the external column of the styloid process, which is frequently uninjured. Lastly, it allows of more convenient fixation.

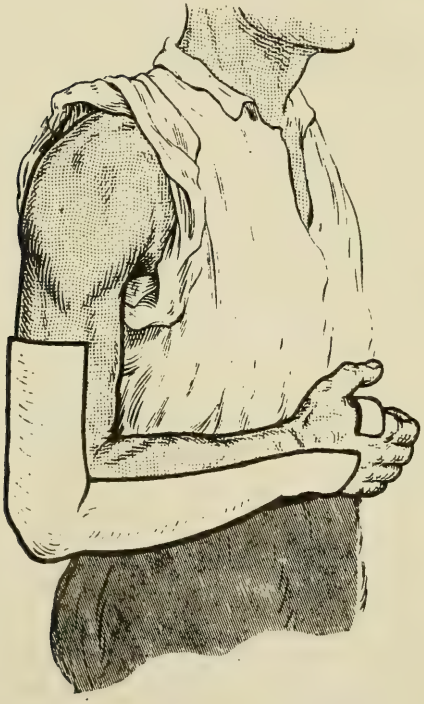


FIG. 83.—Fixation in a position of semi-pronation by means of a plaster trough.

After an aseptic dressing has been put on, fixation is effected by a palmar support, similar to that used after resection of the wrist. It should permit the wound to be attended to without the limb being removed from the plaster.

Assuming the almost certain loss of pronation and supination, the limb should be immobilised, if not at once, certainly later, in a position of semi-pronation with the thumb vertical.

As a rule the subsequent course of the injury is uneventful, and healing occurs without suppuration.

If this is the case, it is decidedly advisable to perform any necessary tendon or nerve suture at an early stage. The wound is, as usual, packed with gauze, and as a rule the result obtained is surprisingly excellent.

In my experience, union occurs in about fifty to sixty days.

5. TREATMENT OF CASES SEEN AT A LATER STAGE, OR ALREADY UNDER TREATMENT.—(*a*) *A case progressing well.*—No operation should be attempted, but strict immobilisation, with the thumb vertical, is required. After X-ray examination, dead splinters and foreign bodies, if any are present, should be removed.

(*b*) *A case arrives in a septic condition.*—The temperature is high and the forearm and wrist are red and swollen. The exact topography of the injury is determined from a radiograph, very careful total esquillectomy is performed, and the medullary canal and the cancellous tissue of the epiphysis, particularly that of the radius, are cleaned with a curette.

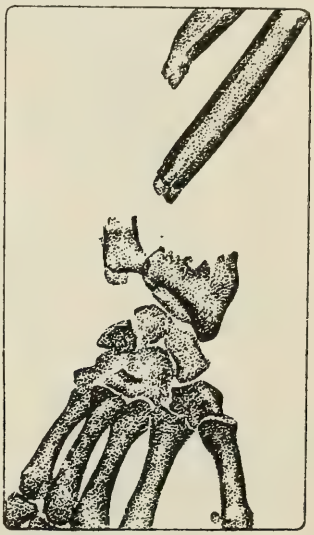


FIG. 84.—Explosive effects from a rifle discharged in the near vicinity of the forearm; wound seriously infected; total sub-periosteal esquillectomy on the third day obviated the apparent necessity of an amputation.

Tracks of pus, if any are present in the region, are laid widely open, and all necrosing tissue is excised. Tendon suture should not be attempted at this stage, the only object of the operation being to save the hand, even at the expense of ultimately sacrificing fingers which, owing to irreparable injury to their tendons, will henceforth be a useless hindrance.

In this way amputation can be avoided even in the worst cases, and a hand preserved with some at least of its fingers useful. Esquillectomy, in fact, with excision of necrosed tissues rapidly arrests infection, and thus preserves tendons which would be destroyed by prolonged suppuration. An extensive operation

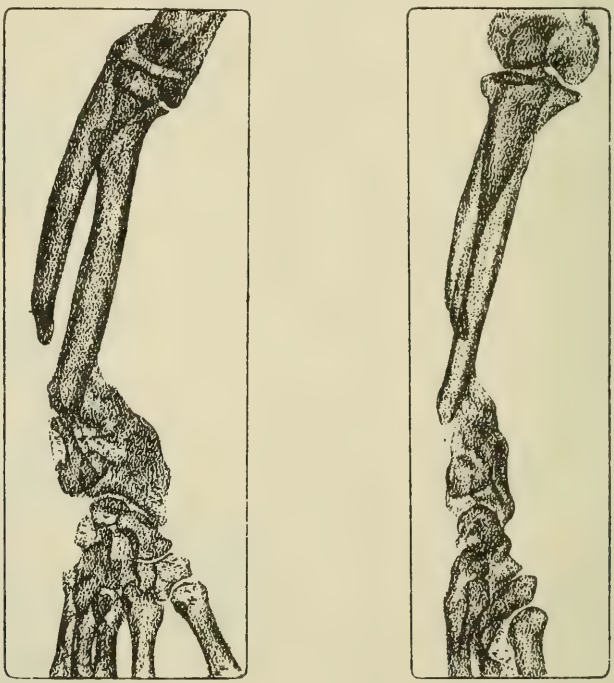


FIG. 85.—Anatomical result three months later of esquillectomy (see fig. 84): solid callus without osteitis; healing complete a month previously. Flexion and extension of the wrist normal, supination very limited. Finger movements almost normal, except in the last two, in which flexion is poor.

is the only truly conservative method, and I cannot too strongly recommend it.

During the first few days fixation is effected merely by means of an iron wire splint, the wound being dressed daily until a marked reduction in the sepsis occurs. When suppuration is totally arrested and the

appearance of the wound is favourable, which will usually be the case in eight to ten days, less frequent dressing is necessary. At this stage it is best to make a posterior plaster trough enclosing the palm and passing round the base of the thumb. The hand is immobilised in semi-pronation, the thumb directed upwards, and the elbow flexed to a right angle (fig. 83).

The plaster extends upwards as far as the middle part of the arm, and not farther downwards than the lower palmar fold, in order to allow of flexion of the fingers.

The plaster is removed for each dressing, that is, every seven or eight days, which is very soon possible when the operative disinfection has been well carried out.

Union usually occurs in two to three months.

If esquillectomy should fail and grave sepsis develop, amputation is unavoidable, but I have always found the former operation sufficient.

## II. FRACTURES OF THE RADIUS ALONE

Two varieties are to be distinguished :
Fracture of the shaft proper,
Fracture of the lower epiphysis.

### A. Fracture of the Shaft.

1. Anatomical Features.—The fracture is usually comminuted, but obviously all varieties are possible. As a rule, there are no radiating fissures.

Serious injury to tendons is almost always associated with this fracture. The extensors are more or less destroyed. In fractures of the distal part of the shaft, all the dorsal tendons of the thumb (the long abductor, the short extensor, and the long extensor) and the two radialis tendons are frequently severed ; injuries to the radial artery and the superficial branch of the radial nerve are equally frequent.

2. Physiological Features.—The upper fragment usually remains in position; it is only displaced in fractures of the upper end of the shaft, when the biceps pulls it forward (*i.e.* flexes it).

On the other hand, in all cases, whatever the position of the fracture, the supinating action of the same muscle comes into play, and, reinforced by that of the supinator brevis, supinates the upper fragment.

The lower fragment invariably undergoes inward displacement towards the interosseous space, owing to the action of the pronators. In fractures of the middle of the shaft it almost always comes into contact with the ulna. Hence there is lateral displacement, in the form of angulation, opening outwards. Similarly, the same muscles induce more or less marked pronation, and complete counter-torsion by rotating the lower fragment on its own axis, in a direction opposite to that of the upper fragment.

The final result is that the fragments correspond neither anatomically nor physiologically, which interferes with union and destroys the essential function of the forearm.

3. Course.—Fracture of the shaft of the radius, unless caused by a short-range bullet, and therefore marked by very extensive injury to muscle and tendons, is very unlikely to prove fatal. The situation of the bone being superficial, fractures due to shell-fragments may not give rise to any immediate and serious septic phenomena. The fact remains, however, that infection is practically constant, and will at least cause necrosis of splinters, which are gradually eliminated and destroy bone-forming tissue. This explains the frequent occurrence of spontaneous pseudarthrosis, apart, of course, from pseudarthrosis due to badly performed esquillectomy.

Further, the functional significance of tendinous lesions increases if the wound suppurates; an injury to a tendon that could be repaired after aseptic

healing of the wound becomes incurable when infection causing necrosis of the fragile extremities finally destroys a considerable proportion of the length of the tendon.

Lastly, a fracture which originally seemed quite mild may become a very serious affair if prolonged suppuration causes extensive muscular sclerosis.

The functional prognosis therefore depends on early disinfection of the fracture ; it is; in fact, essential to the future safety of the hand that these fractures should not suppurate. Asepsis is a necessity from another point of view : the complex arrangement of muscular origins in the forearm necessitates perfect reduction and strict subsequent fixation, and to induce and maintain these conditions satisfactorily in spite of prolonged suppuration is a difficult matter.

If none of this is effected, fracture of the shaft of the radius is equivalent to mutilation : the forearm becomes fixed in extreme pronation, with marked radio-ulnar dislocation ; the muscles and tendons destroyed are definitely and permanently lost, and the hand is an impotent, clumsy, useless, and painful appendage.

But this is not all : the contraction of the infected soft parts in the neighbourhood of the fracture, the natural tendency of the muscles to pull the lower fragment upwards and inwards, and the loss of bone caused by the elimination of splinters and destruction of their periosteum, diminish the length of the radius, and accentuate its original deviation deformity. The callus perpetuates this vicious position, and the two bones of the forearm are no longer in harmony ; the ulna tends to adapt itself to the dimensions of the radius by bending and causing a curved projection on the internal surface of the forearm, but this is insufficient to compensate for the diminution in length of the bone with which it is connected ; its styloid process appears to be displaced from the carpus and encroaches

on the base of the hand, which it appears to be forcing outwards. This, however, is only an appearance. In reality the hand follows the radius, to which it is more closely attached, outwards with the lower fragment of that bone. This displacement is due to the upward and inward movement of this part of the shaft, and in this way very troublesome radial deflection of the hand is produced. In itself, and altogether apart from any musculo-tendinous lesion, or counter-torsion, this deformity interferes considerably with the movements of pronation and supination.

Nor should it be regarded as a rare occurrence. In different degrees it is very frequent, and this frequency necessitates certain treatment which will be discussed later.

In short, fracture of the shaft of the radius, if infected or badly reduced, is liable to cause pseudarthrosis, damage to tendons, loss of pronation and supination, and outward deviation of the hand.

It is therefore not a fracture which can be regarded as a mild lesion.

4. Indications for early Treatment.—As has been said, every effort should be made:

(*a*) To prevent suppuration;

(*b*) To induce and maintain reduction;

(*c*) To ensure that, after union, the shaft of the radius will be equal in length to that of the ulna.

This may be effected in the following way:

(i) *Asepsis is assured by early sub-periosteal esquillectomy;*

(ii) *Reduction by immobilising in the position of full supination;*

(iii) *Restoration of equality in length of the two bones by secondary resection of a small piece of the ulna, if the interfragmentary gap in the radius is rather wide.*

It may be thought that the third clause of the treatment is necessitated by the first, which causes a loss of bone-substance, and it will perhaps be said that if

adherent splinters were not removed and the radius were therefore not diminished in length, resection of the ulna would be unnecessary. But the objection is scarcely worthy of attention: the study of end-results, such as is possible at medical boards and orthopædic consultations, shows that radial deflection of the hand occurs very frequently in cases which have suppurated for long periods without having had an esquillectomy done, and in which, therefore, an interfragmentary periosteal callus should consequently have been most easily able to form. In actual fact, the best method of preventing diminution in length of a fractured bone is to facilitate osseous proliferation within the cylinder of periosteum, by performing a correct esquillectomy.

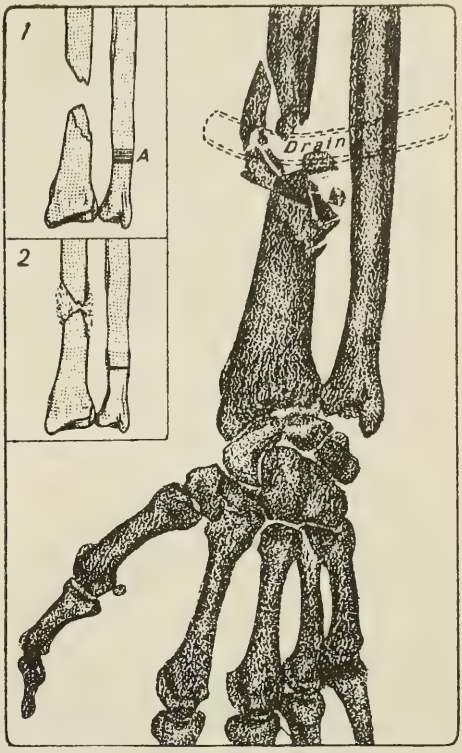



FIG. 86.—Fracture of the shaft of the radius by a shell-fragment, treated at the front by simple transosseous drainage. Serious infection; case complicated by fracture of the humerus. These two fractures were treated on the third day by total sub-periosteal esquillectomy. After six weeks union had occurred in the humerus, but not in the radius; tendency in the hand to outward deviation. I resected ½ inch of the ulna without interfering with the radius. Fixation by plaster (corrective) was followed by rapid union. Complete cure in three months, with all movements preserved.

After clearance, resection of the ulna is advisable if the interfragmentary radial gap exceeds an inch in length, not so much to avoid pseudarthrosis, which is unlikely to occur, as to ensure perfect harmony between the two associated bones. The physiology of the question shows that the radius and ulna being connected as they are, the slightest diminution in length of one of them causes dislocation of one of their joints, and consequent serious disorder of function. I have practised this resection of the ulna for several months past, and during that period have noticed a considerable improvement in functional recovery in the patients concerned.

5. TECHNIQUE.—*Esquillectomy* is effected by means of an external lateral incision, widely exposing the area of bone injury. The clearance should be strictly sub-periosteal, and in almost all cases, total; careful attention to detail is required. The flexors should not be disturbed from beneath, and as far as possible the wound should not be plugged from the internal side.

*Reduction* is easily effected by immobilising the elbow, forearm, and hand in a posterior plaster trough, the position being one of full supination, the palm of the hand being horizontal and facing upwards, and the hand inclined strongly towards the ulnar side. This plaster is retained or renewed until union has begun, which should occur in about eight weeks.

After four or five weeks, and after examination of radiographs taken from each aspect, the plaster is removed for investigation of the callus. If the interfragmentary space is rather wide (more than 1 inch), and particularly if the ulna is projecting a little on the internal aspect of the forearm, *about 1 inch of the ulna should be resected*. The best moment for this is the stage at which the callus, though still soft, is clearly visible in the radiographs as a darkish shadow in and around the interfragmentary space.

This resection, which should be strictly sub-periosteal, is conducted in the following way : a point should be chosen at some distance from the fracture, and the lower end of the ulna is ideal from this point of view. The bone is isolated with the rugine, the edge of which should be kept in close contact with the compact bone, in order to leave as much periosteum as possible in

FIG. 87.—Fixation in a plaster splint in a position of supination, the hand inclined to its ulnar side, after secondary resection of the ulna, following esquillectomy for fracture of the radius.

the wound. The entire circumference of the bone being well exposed, a chain or Gigli saw is passed round it, and a section of bone about 1 inch in length is excised. There need be no fear of removing too much ; in practice there is a natural tendency to be very economical and to remove too little. It is better, when possible, to fix the two fragments by means of a metal clip, wire, or Lambotte plate ; I have often,

however, dispensed with this. The wound is simply plugged and not sutured; the piece of bone removed from the ulna may be placed in the interfragmentary gap of the radius if this is wide enough. It is of advantage to re-expose the radial region, and to irritate it a little with the curette in order to stimulate bone-formation. The forearm is then immobilised in supination as before, with the hand deflected towards its ulnar side.

After this operation, the rapidity of callus-formation and the functional perfection attained are surprising.

This slight interference, in fact, absolutely prevents pseudarthrosis and deviation of the hand, and ensures maintenance of the anatomical conditions necessary for the recovery of pronation and supination.

6. The Treatment of cases examined at a late stage, or already under Treatment.—(*a*) *A case arrives after two, three, or four days, doing well.*—If there is no trace of infection the fracture need merely be reduced and immobilised in supination in a posterior plaster. In this exceptional case, in which the absence of infection abolishes the necessity for esquillectomy, all efforts should be directed to ensuring functional recovery. After what has already been said, it is unnecessary to emphasise the importance of placing the forearm in supination, and of verifying reduction by a radiograph. If signs of slight infection should appear later, and splinters are eliminated, it should be decided by clinical and radiographic methods whether the length of the ulna should be reduced as a precautionary measure, since otherwise an originally benign fracture might finally produce deplorable functional effects.

(*b*) *A case is seen in a septic condition.*—Subperiosteal esquillectomy and drainage should be performed at once; total clearance is almost always necessary, and particular care should be exercised in separating the periosteum.

Fixation is effected during the first few days by a simple trough for the forearm. At the end of seven or eight days, when the infection has been arrested and suppuration has almost ceased, a temporary interrupted plaster should be made, the position being one of supination. This type of appliance has already been described (fig. 79).

It is often useful to increase the rigidity of the exposed part of the forearm by incorporating a small wooden splint in the outer part of the dressing, which acts as a rigid external support. It is applied to the internal aspect and fixed firmly in place by a bandage. There is a natural tendency to angulation of the bones, when a plaster of this kind is used which does not immobilise by any means perfectly, and this tendency is well counteracted in the way described.

This appliance is merely temporary. As soon as the wound need only be dressed at long intervals, it is preferable to immobilise in the usual plaster trough. Frequently, in cases such as have been described, precautionary resection of the ulna should be performed. Its indications have already been given: if the ulna tends to adapt itself to a diminished length by curvature, if the radiograph shows obliquity of the radio-carpal line and distal radio-ulnar diastasis, and if the interfragmentary gap exceeds 1 inch in width, I believe it perferable to have recourse to this without waiting for actual deviation outwards of the hand to take place.

(*c*) *A case is seen with a sinus.*—This is the ordinary case of fistulous osteitis, and the usual treatment is required.

(*d*) *A case is seen with vicious union in a position of extreme pronation.*—This position is extremely troublesome, and seriously interferes with the functions of the hand. It is due, as has been explained, to double rotation in opposite directions of the two fragments of the shaft, which incorrect fixation has failed to

rectify. This vicious disposition must be broken down to permit a second reduction of the fracture.

In this connection, two possible cases must be considered:

1*st Case. The callus is regular, and not fistulous.*— The bone as a whole, instead of possessing a curvature with a convexity outwards, forms an angle the apex of which is close to the ulna. The best course is to fracture the lower fragment at some distance from the callus. An osteotomy is therefore carried out below the fracture, and the small incision required for this purpose is not sutured, since plugging and drainage are effective in stimulating ossification The forearm is at once immobilised in a posterior plaster trough in a position of supination. After verification by a radiograph, the appliance is kept in place for at least a month. At the end of this period the plaster may be removed and the wound dressed. Fixation should, however, be prolonged for a further fortnight or three weeks in order to obviate a return to semi-pronation by torsion of the soft callus. The results of this operation are excellent; I have succeeded, in two cases, in reproducing almost normal conditions.

2*nd Case. Fistulous osteitis, with a large callus.*— Suppuration must first be arrested and complete cure obtained the method described in the preceding case should then be adopted.

(*e*) *A case is seen with pseudarthrosis.*—Unlike pseudarthrosis of the ulna, that of the radius has serious effects: extreme pronation is induced in the lower fragment, the supinators being unable to counteract this; the hand is deflected outwards and is impotent; there is dropped wrist and inability to grasp with the fingers. The curvature of the ulna, due to its disproportionate length, is painful. Intervention is a necessity.

If the gap in the bone is not more than ½ inch in width, direct osteosynthesis by plate or clip is possible,

after removal of the intervening fibrous tissue and trimming of the extremities of the bone. But this does not correct the deviation of the hand, and the ulnar curvature remains. Even in these cases I prefer, after trimming the radius, to resect from the ulna a sufficient length of bone to bring about perfect reduction; union in the radius then follows very rapidly.

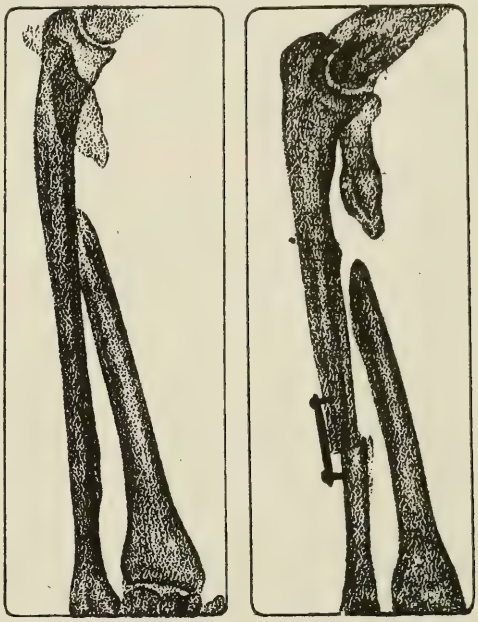


FIG. 88.—Fixation of the hand in extreme pronation following a seriously infected fracture of the radius, cured with a pseudarthrosis. Reduction under an anæsthetic was impossible. Correction of the vicious position was obtained after osteotomy of the ulna. The result is excellent. The hand is semi-pronated with the thumb upwards, small movements sufficient for professional purposes being still possible. The result dates from ten months previously.

When the gap is more extensive, there is no alternative to ulnar resection, but the ulna should be fixed at once by a clip or plate, as has been advised by Nové-Josserand. If this precaution be not taken, cure of the radial pseudarthrosis will often follow, while the surgical fracture of the ulna fails to unite. Nové-Josserand has quoted cases of this. I myself have been obliged in two cases to plate the ulna again when union had already occurred in the radius.

By this method consistent results will be obtained

in all cases where the width of the interfragmentary gap does not exceed 1½ inches. The same cannot be said of grafting, which many surgeons have attempted with few successful results: apart from its serious technical difficulty, account should be taken of suppuration, the main cause of its failure, to which it is rendered liable by the presence of latent organisms in the bone and soft tissues. I have seen six cases at medical boards in which the graft had been eliminated or reabsorbed.

Bone-grafting can therefore not be recommended as a reliable method in war-surgery. Consequently, when the procedure previously described (trimming of the radius and resection of the ulna) is not possible, the problem is difficult to solve.

In a case of pseudarthrosis in the proximal part of the bone, I obtained satisfactory results from simple corrective osteotomy of the ulna, which permitted restoration of the hand to a good position. The result, which dates from ten months ago, has been maintained (fig. 88). The pseudarthrosis is not cured, but the vicious position of the hand is corrected by what may be described as therapeutic counter-torsion.

Lastly, if there is very extensive loss of bone, the best solution appears to me to be inferior radio-ulnar arthrodesis, as described by Nové-Josserand, or the production of radio-ulnar synostosis low down, suggested by Ombrédanne.

**B. Fracture of the Lower Radial Epiphysis.**

1. Anatomical Features.—Small splinters with irregular extremities are frequently formed, their long axes corresponding to that of the bone; the articular surface is usually intact, and frequently the external surface, which forms the prolongation upwards of the styloid process, is also left uninjured; the epiphysis is partially broken up, but the fracture,

which is rarely complicated by fissures, usually remains extra-articular.

The splinters frequently remain in place, arranged in parallel formation, and separated by fissures; the appearance of an epiphysis thus composed of segments in juxtaposition is very characteristic.

There is almost always association of serious injury to tendons, and often laceration of the radial artery.

2. Physiological Features.—Little muscular action is exerted on the lower fragment, which usually remains in place, merely inclining slightly upwards and inwards without causing any dorsal prominence. I have always found it in pronation, either because the hand was in this position when the injury occurred, or owing to continued action of the pronator quadratus. The upper fragment assumes a position of supination, except in cases where the fragments are, so to speak, entangled, which sometimes occurs.

The study of a few fractures by bullets causing punctiform wounds proves the reality of this counter-torsion: I have twice found cases which healed without suppuration, and were cured with the hand fixed in extreme pronation; not the slightest degree of supination was possible, in spite of complete integrity of the joints (including the lower radio-ulnar joint).

In actual fact, the displacement of the lower fragment upwards and inwards is of much greater ultimate importance. Its actual result is to shorten the radius, causing outward deviation of the entire hand, and consequently serious future functional disturbance.

3. Course.—As a rule, serious local infective phenomena develop rapidly, and their intensity depends on the extent to which the projectile, in traversing the cancellous tissue of the epiphysis, has ground into it fragments of the sleeve, or, as frequently happens, soil. These foreign materials are also found beneath and between the tendons. Gas gangrene and similar

infections do not develop, since there are no muscles in the region. Tracks of pus develop along the tendons, beneath the skin, which is swollen and tense, and the progress of the infection soon outstrips the possibilities of surgical interference; the forearm is little more than a purulent sponge, giving rise to constitutional disturbance which multiple incisions are powerless to arrest, and amputation may eventually be the only resource. Even if the infection is successfully controlled, the muscles undergo sclerosis, tendons are eliminated or destroyed, the hand remains purplish and œdematous, and function is irremediably lost.

FIG. 89.—Union of an intra-epiphyseal fracture of the radius, with formation of a central cavity; upward displacement of the lower radial fragment, hand deviated to the radial side; considerable interference with movement. Orthopædic resection of the ulna was indicated, and would have avoided this.

Earlier intervention is therefore necessary: the situation may be controlled by an operation on the bone at a very early stage, but even in this case the tendons are too often destroyed, and the fingers remain stiff and almost useless.

In less serious cases, chronic infection of the fractured region destroys the marrow of the epiphysis; the callus which forms is large and peripheral, concealing a central cavity which remains fistulous for a long period.

Further, sepsis having caused necrosis, not only of the splinters but of the extremities of the epiphysis and shaft, the bone, already shortened by the passage upwards of the lower fragment, is very much reduced in length, and the callus renders this shortening permanent. At the same time, deviation of the hand occurs, and ultimately, when the wound has healed,

the surgeon is surprised to find serious outward deflection of the hand.

It is absolutely necessary to obviate these unfortunate occurrences and to ensure a good recovery of the injured region.

4. INDICATIONS FOR EARLY TREATMENT.—The following steps should be taken :

(*a*) Early operative disinfection of the fracture, which will ensure asepsis, and therefore easy maintenance of a satisfactory reduction ;

(*b*) Fixation in a suitable position ;

(*c*) Early operative correction, preventive if necessary, of external deviation of the hand.

Immediate disinfection is effected by sub-periosteal esquillectomy at an early stage, which, judging by my own experience, should in this case be total. This is a delicate operation, since the splinters are small, and their periosteum is very thin and adherent, as in all epiphyseal regions.

The fracture is approached by a dorsal incision, in addition to which a palmar incision will often be necessary, even at the expense of sacrificing the radial artery.

The epiphysis and medullary canal of the shaft should be scraped out with great care ; a large number of small fragments of bone pulverised by the impact will usually be brought to light in this way. The tendons should be carefully examined, and it is for this examination that a palmar incision is particularly necessary ; surprise will often be caused at what is found in contact with them.

This process of cleaning completed, it will usually be found well to remove a certain amount of bone from the dorsal surface of the epiphysis, rather than leave the latter in the shape of a completely empty shell. This should only be done after careful removal of the periosteum with a rugine.

Immediate repair of the lacerated tendons will often

be possible; it should preferably be effected with catgut.

The wound is then plugged with aseptic gauze, and the forearm immobilised by a plaster trough in a position of semi-pronation, the thumb upwards, and

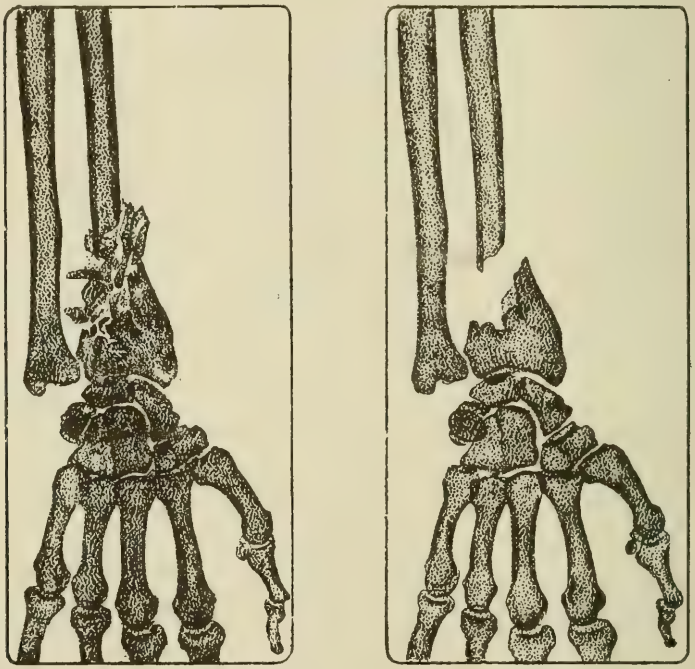


FIG. 90.—Fracture of the lower end of the radius, evacuated from the front after having a drainage tube passed through the epiphysis (without anæsthetic); wound seriously infected. Total esquillectomy during pyrexia on the third day; a number of pieces of clothing removed from close contact with the cancellous tissue of the epiphysis and the medullary canal of the shaft. Saline dressings, followed by aseptic dressings. Cure without pseudarthrosis in three months.

the hand supported on its ulnar side. During the first few days I believe that this position is preferable to that of supination, which renders the examination and dressing of the wounds much more difficult.

Fixation should first be effected by a metal splint,

then, at the end of some days, by a plaster trough, applied to the ulnar side of the forearm and reaching well above the elbow.

At the end of four or five weeks an X-ray examination is made. At this stage the shadow of the periosteal cylinder will usually be clearly visible, indicating that callus is in process of formation. The position of the styloid process of the ulna and the direction of the radio-carpal line must also be examined closely. If the styloid process seems to be situated lower down than it should be, if it descends lower than the styloid process of the radius, and if the radio-carpal line is directed obliquely upwards, preventive resection of about half an inch of the ulna, followed by plating of the latter, should be performed without delay (see p. 471).

After the operation, the forearm is immobilised for five weeks in the position of supination, unless the radiograph shows injury to the radio-ulnar joint. In this case, semi-pronation with the thumb upward is preferable as a permanent position, since it would be hardly reasonable to expect recovery of the power of pronation and supination.

5. TREATMENT OF CASES EXAMINED AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case is progressing well after some days, without operation.*—There is no pyrexia or suppuration; all that is necessary is immobilisation in full supination for a month, the hand resting on its ulnar side, in order to counteract the tendency to upward and inward deviation of the lower fragment, and therefore to prevent displacement of the hand. A plaster trough is the best fixation appliance for this case, and in many cases it should be left in position for more than a month, union in epiphyseal fractures being sometimes very slow.

(*b*) *A case arrives in a septic condition.*—After determining the existence and position of splinters and foreign bodies by means of a radiograph, total sub-

periosteal esquillectomy should be performed immediately. The epiphyseal cavity and medullary canal are cleaned with the greatest care, tracks of pus are followed to their limits, and necrosed tissue is excised.

After a comprehensive operation, a hypertonic saline dressing is applied to the wound, and fixation effected by a trough splint.

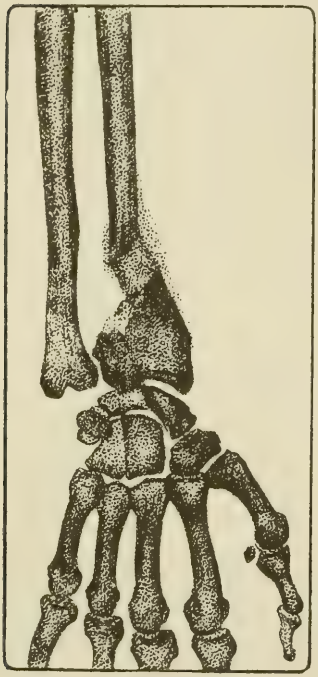


FIG. 91. — Radiograph after two and a half months. Cf. figs. 89 and 90.

The wound should be dressed daily, if necessary under an anæsthetic (ethyl-chloride). Any necrosed débris or small fragments of bone which have been overlooked are removed with forceps. If pus has tracked upwards, this should be drained, not with drainage tubes, but by incising the skin over the affected area. Sepsis will usually be arrested in five or six days. This method has up to the present always accomplished my object; I have never been obliged to amputate in such a case, even in those that have first come under my care at a late stage in a seriously septic condition, and I have never lost a case of this kind.

(*c*) *A case is seen with a sinus.*—This almost invariably leads to a cavity in the interior of the epiphysis, in which are enclosed splinters which were not originally removed; their removal, and scraping of the cavity is usually not enough to effect healing. The cavity must first disappear, and this habitually necessitates a levelling-down of the bone.

(*d*) *A case is seen with a pseudarthrosis.*—In this

case there is usually outward deviation of the hand. The styloid process of the ulna forms a marked prominence in an abnormally low position. In order to effect a cure, the extremities of the radius must first be trimmed, and all fibrous tissue between them excised; the ulna is then shortened to a sufficient extent to correct the radial inclination of the hand,

FIG. 92.

FIG. 93.

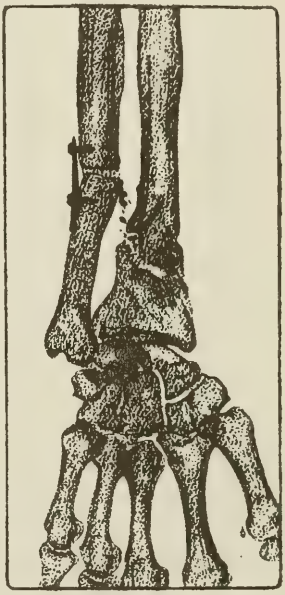


FIG. 94.

FIG. 92.—Radial pseudarthrosis with club-hand after fracture by bullet, never operated upon.

FIG. 93.—The same case seen from the side.

FIG. 94.—Cure after trimming of the radial extremities, resection of half an inch of the ulna, with application of a Lambotte plate.

and at the same time to approximate the two fragments of the radius. The two fragments of the ulna are united by a clip or plate, and the section of the ulna removed is placed in the interfragmentary gap of the radius. The ulnar wound is closed, the radial wound plugged. Careful immobilisation in the correct position, prolonged for about two months, will enable

union to take place, if a sufficient length of the ulna has been resected. There is a tendency to exercise economy in this connection, leading to failures which could well have been avoided, as occurred in one of my own cases. On the other hand, I have twice been successful with the procedure: in one of these cases an autoplastic graft had previously been introduced and reabsorbed without suppuration.

## III. FRACTURES OF THE ULNA

I shall only deal with fractures of the shaft of the ulna; fractures of the olecranon are articular fractures, requiring sub-periosteal esquillectomy if there is no other fracture present * and re-resection if there is associated fracture of the neighbouring epiphyses. Fractures of the styloid process are comparatively trivial; after prompt esquillectomy, they heal rapidly and leave no functional disability.

Fractures of the shaft proper require separate study.

1. Anatomical Features.—These fractures, in contrast with fractures of the ulna in civil life, are generally not complicated by dislocation of the upper extremity of the radius. It is easy to understand why.

All types are possible, but the most usual in my experience is the type involving one large short fragment: a wedge-shaped mass is detached, and rarely more than two or three small splinters are present on the other side of the shaft. On the other hand, the projection of small fragments into the medullary canal is not unusual. Associated injury to the ulnar nerve occurs in a fairly large number of cases.

2. Physiological Features.—It is a constant

* In very favourable conditions it would be perfectly possible, after early operative disinfection, to treat certain fractures of the olecranon as peace-time fractures, but this can only be done in a quiet sector, where the possibility of close supervision is guaranteed. In the event of large numbers being admitted or evacuated, any form of bone-suture is definitely contra-indicated.

feature that the upper fragment remains in position, while the lower is displaced outwards by the powerful muscular action of the pronator quadratus, which forces it towards the shaft of the radius, with which it frequently comes into contact, and difficulty is sometimes experienced in reaching it unless the hand is placed in supination.

3. COURSE.—This is not a serious form of fracture ;

FIG. 95.

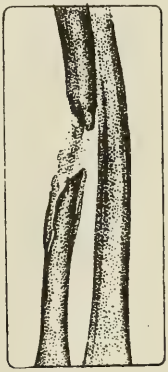


FIG. 96.

FIG. 97.

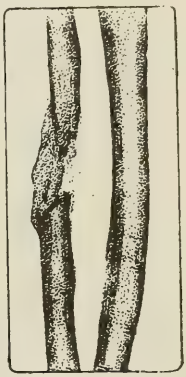


FIG. 98.

FIG. 95.—Fracture of the ulna by a shell-fragment with fissures of the shaft ; slight infection. Radiograph on the fourth day.

FIG. 96.—Radiograph eight days later, after sub-periosteal esquillectomy.

FIG. 97.—Radiograph three weeks after esquillectomy. The fissures are no longer visible.

FIG. 98.—Radiograph on the thirty-fifth day when healing of the soft parts has been complete for a week ; post-operative course had been aseptic. (See the ultimate result, fig. 26, p 330.

owing to the superficial position of the ulna, the area of the fracture is naturally exposed, and it is only in fractures high up the bone beneath the thick flexor muscles that serious infections occur.

As a rule, infection merely gives rise to a local affection of the bone, necessitating incisions and drainage, and ultimately leaving traces of its existence in the form of a cavity in the bone, enclosing a few small sequestra.

It is not rare for pseudarthrosis to follow suppuration in these cases. It is true that pseudarthrosis of the ulna is not a serious inconvenience, but that is no sufficient reason for not avoiding it. A further danger is that of injury to the flexor muscles, as was discussed on p. 455

4. INDICATIONS FOR EARLY TREATMENT.—Here, as in other regions, sub-periosteal esquillectomy is so reliable a guarantee against asepsis, that if there is an accompanying injury of the ulnar nerve, this should be sutured at once. The fracture is approached by a lateral incision, the flexor muscles being displaced by a retractor if the level of the injury necessitates this. Clearance consists in separating the large short fragment with a rugine as well as the few small isolated pieces of bone found in the region of the fracture. The medullary canal is gently cleaned with a small curette and the cavity left is plugged with gauze. Fixation is effected by a posterior plaster splint, the forearm being supinated, with the hand flat and the elbow flexed.

In general, the subsequent course is uneventful, and union occurs in thirty to forty days. It is well to keep on the plaster rather longer: interrupted appliances and continuous extension are useless.

5. TREATMENT OF CASES FIRST SEEN AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case arrives going on well.*—Fixation of the forearm in supination is all that is necessary; a posterior plaster trough is applied for this purpose.

(*b*) *A case arrives in a septic condition.*—Immediate sub-periosteal esquillectomy is essential: the whole region of the fracture is cleaned through a fairly long lateral incision, all splinters being separated with the rugine and removed. During this process the condition of the flexor muscles should be carefully examined, as small splinters are frequently found in them and may give rise to prolonged suppuration

which has a serious effect on muscular contraction and causes grave functional disorder. At the same time all devitalised fascial tissue should be removed.

This treatment, if carried out with sufficient attention to detail, and not merely as a rapid draining process, will be successful in arresting infection and safeguarding the functions of the hand, which would be permanently

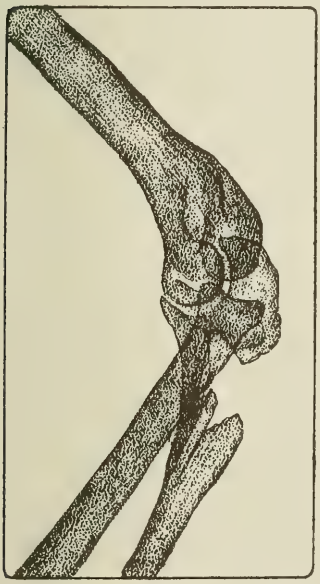


FIG. 99.—Narrow sub-articular pseudarthrosis of the ulna, following early extra-periosteal esquillectomy. The wound healed very rapidly, but there was no regeneration of bone. The continuity of the ulna is provided by a narrow osseous band, in contact with the shaft, but not united to it. All movements are possible and almost normal.

FIG. 100.—Removal of the lower two-thirds of the ulna by extra-periosteal resection performed at the front. The patient was cured very simply, and there is virtually no disturbance of function; pronation and supination are performed well, but the forearm is weak: a leather wristlet is useful.

and seriously jeopardised if prolonged suppuration took place in contact with the flexors and their tendons. If in the course of treatment flexion of the fingers is seen to occur, continuous elastic traction should be applied without delay to correct their position and prevent serious cicatricial contracture (see p. 455).

(*c*) *A case arrives with a sinus.*—The sinus almost invariably leads into a small cavity, in which is a small sequestrum embedded in granulations. Hypertrophic callus and extensive formation of sequestra do not occur in the ulna, frequent as they are elsewhere. This is not surprising, when the usual type of fracture of this bone is considered. But it should not be supposed that it is sufficient to remove the osseous débris and scrape the walls of the cavity in order to cure the sinus. In these cases I have always found the medullary canal blocked on each side, forming a closed cavity which is a frequent cause of subsequent trouble. If a cure is to be assured, it is absolutely necessary to clear the cavity completely, cut down the bony walls of the cavity, and reduce the infected area to a smooth and regular surface. This done, rapid cure will be effected without the use of antiseptics. If necessary, sub-periosteal resection of the infected section of bone may be performed.

(*d*) *A case is seen with pseudarthrosis.*—In general, a pseudarthrosis of the ulna causes little functional disability of the forearm and hand. In the lower part of the bone it is only slightly troublesome, and if the patient wears a leather wristlet, he may be said scarcely to notice it. In the upper half of the bone it causes little inconvenience. If the loss of bone is extensive (1½ inches), slight curvature sometimes occurs, due to the weight of the hand when the forearm is raised, but this is not a constant feature. My impression, based on the observation of three cases, is that even more extensive loss of bone (3 to 4 inches) causes no more trouble (fig. 100).

In fact, the disorder in function is not usually sufficient to justify intervention. I have seen a dozen of such pseudarthroses or gaps in the bone without operating on one of them. This confirms the opinion of Nové-Josserand, who advises refraining from operation, even in the severer forms.*

* A. Broca, in his recent book on the osteo-articular sequelæ of gunshot wounds, is of the same opinion (see "The After-effects of Wounds of the Bones and Joints," by Prof. Aug. Broca, Military Medical Manuals, University of London Press).

## CHAPTER XIV

### MULTIPLE FRACTURES OF THE UPPER LIMB

THE early disinfection of fractures by sub-periosteal esquillectomy is never more urgently required than in the numerous cases which occur of multiple fractures caused by fragments of an exploding shell. By careful cleaning of all the wounds, which will frequently amount to a somewhat lengthy operation, surprising results may be relied on if this be done as a primary or even as a secondary measure.

Further, it can be laid down as a principle, that when muscles, arteries, and nerves are not destroyed to such an extent as to render subsequent use of the limb totally impossible, amputation should not be performed for multiple fractures. It is better to ensure a favourable course for the fractures by multiple sub-periosteal esquillectomy, since much may be expected from periosteal regeneration.

The immediate fixation in these cases can only be effected by a large trough splint : Delorme's flat trough is very suitable from this point of view. A satisfactory

FIG. 101.—Fracture of the humerus with intra-medullary missiles, fracture of the radius and ulna, of the fourth and fifth metacarpals, and of the metacarpal phalanx of the fourth finger. Multiple wounds by shell-fragments on the upper limb and thorax ; infection of all the wounds. Intra-febrile sub-periosteal esquillectomy on the fourth day, three fingers being removed owing to the extent of the lesions of the soft parts. Later, sub-periosteal resection (nineteenth day) of the lower extremity of the ulna. Result obtained after two and a half months ; wounds almost completely healed, fractures united. The periosteal reproduction of the lower extremity of the ulna will be noted. Manual correction of the flexion of the humeral callus was possible.

FIG. 101

appliance may be built of wide wooden slats the length of the limb, extending from the shoulder to the tips of the fingers.

As soon as possible, however, a suspension apparatus should be employed. Cure may certainly be effected by other methods, and the case of which radiographs are reproduced (fig. 101) was kept for the whole period of treatment in a Delorme trough.

A suspension appliance, however, obviates pain ; it is also more convenient for dressing and may be

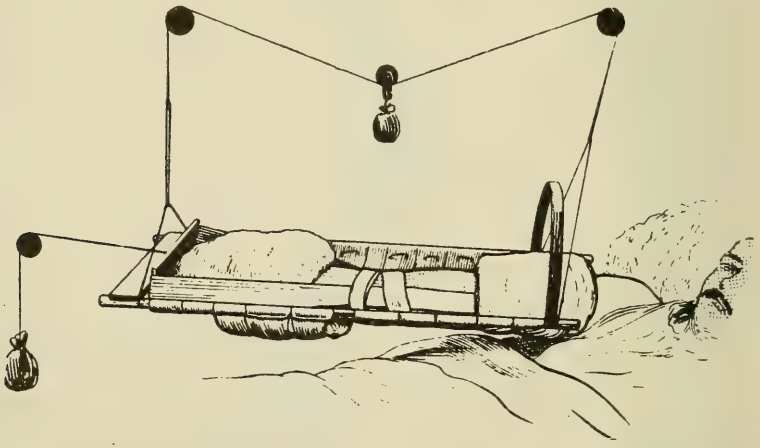


FIG. 102.—Continuous extension on the arm and wrist in a suspension appliance, for shattering of the humerus and radio-carpal fracture. Esquillectomy was performed in the case of the humerus ; the wrist was resected. For some days continuous extension was made on the hand, the bands being fixed to the stirrup of the humeral extension. Weight of extension, 1,500 grammes ; counterpoise weight, 4 kilogrammes. (The frame is not illustrated.)

combined with continuous extension. In short, a better result is obtained at less inconvenience.

Two types of suspension apparatus may be used : the type in which extension is applied to a horizontally suspended limb (fig. 102), or another in which the arm is extended horizontally and the forearm vertically (fig. 65, p. 428 ). Experience leads me to recommend the latter from all points of view.

The arm is placed in a hammock with continuous horizontal extension applied above the elbow ; the forearm is flexed and suspended at right angles ; traction is exerted on the palm of the hand or on the fingers, if the wound is very low down, but on the proximal part of the wrist if possible. Patients readily become accustomed to this : I have two in course of treatment at the present time for double lesion, and both fractures are progressing as uneventfully as could be desired.

I have frequently treated fracture of the humerus, radius, ulna, and metacarpus in the same patient. These cases gave more trouble than the two of which I have just spoken, and the superiority of suspension fixation seems to me to be beyond discussion.

## CHAPTER XV

## FRACTURES OF THE FEMUR

THREE main varieties are found in practice :

1. Sub-trochanteric fracture.
2. Fracture of the shaft proper.
3. Supra-condylar fracture.

### I. Sub-trochanteric Fracture

1. ANATOMICAL FEATURES.—There is almost invariably comminution, the largest splinters rarely exceeding 2 inches in length ; frequently the violence of the impact forces them far into surrounding muscles and into the medullary cavity, fragments often being found in contact with the sciatic nerve, or even within it ; I have personally removed them on two occasions from the nerve trunk.

The end of the shaft, as well as that of the upper fragment, are usually jagged and irregular, but not fissured. I have never seen cracks running up into the thickness of the trochanter or to the neck, and I believe it to be very exceptional for fissures to produce an articular fracture even in an extensive injury of this kind.

There is very often considerable muscular damage, whether the skin be lacerated or not ; in some cases the femoral vessels are injured by the projectile, and the sciatic nerve is often torn or severed.

2. PHYSIOLOGICAL FEATURES.—Muscular action displaces the upper fragment in an invariable and

characteristic way: the muscles, passing from the pelvis to the trochanter, the psoas, iliacus, and pectineus, displace it upwards and outwards, and it assumes a position of abduction, flexion, and external rotation.

On the other hand, the lower fragment, under the influence of the adductors, is carried upwards and inwards, and to a certain extent is internally rotated. Its displacement upwards is sometimes such that it appears to be riding over the upper fragment; in any case splinters may be found behind the latter, a point that it is well to remember from the operative point of view.

As a matter of fact the displacement of the upper fragment is the more important, and gives the distinguishing feature to this common type of fracture (fig. 103).

3. COURSE.—Sub-trochanteric fracture is a very serious injury, which often leads to death within a few hours from simple shock, or by secondary infection unless this danger is met by early operative treatment.

In cases which run their course with only a mild focus of infection, a large bony callus is formed, enclosing sequestra which are difficult to find, and whose removal does not always bring about closure of the sinuses.

On the other hand, unless the fracture is reduced with a careful eye to its physiological features, union may fail entirely, or may occur with marked deformity and serious shortening.

If, however, the fracture is treated by early and thorough operative disinfection which preserves the elements essential to the formation of bone from the periosteum, and if an intelligent reduction is performed in time, perfect structural and functional recovery occur, the patient suffering no deformity and very little shortening. I have in my wards two men suffering from this variety of fracture: one got up after fifty-seven days, the injury being completely sound, the

other after eighty-two days. In each case the callus allowed of their lifting the thigh at the end of forty-two to forty-five days. The shortening does not exceed half an inch.

4. Indications for early Treatment.—In subtrochanteric fractures serious symptoms usually appear immediately, the patient suffers from great shock, from which it is very difficult to rouse him.

Moreover, owing to the difficulty of transport, cases are often not seen until they are in a seriously septic condition. Consequently it is more true of fractures of this region than of any other, that immediate operations are the exception.

In cases of shock, immediate operation is impossible; it would prove fatal by augmenting the shock. In the absence of more precise theories by which to direct the ideal treatment of shock, every effort should be made to counteract the peripheral vaso-constriction: with this object the patient is kept warm, and lying down with the head low, complete repose is induced by an injection of morphine, and camphorated oil and adrenalin are used as stimulants.

In a few hours' time the operation may be performed; it should be rapid and merely do what is urgently required, leaving complete esquillectomy to a later stage. In any case, the shock does not render amputation preferable to esquillectomy; *it only indicates an operation in two stages.*

What should be done if shock is not severe?

Extensive muscular damage and the existence of arterial lesions only rarely contra-indicate a conservative operation. This being so, the best course is usually to trim the cut muscular surfaces thoroughly with scissors, to sacrifice all contused soft tissues, and to tie all bleeding points: ligature of the femoral artery has no untoward effect on the fracture.

If, however, the extent of muscular injury is really too great, if there is a large hematoma and infiltration

of blood far along the thigh, and if the limb below is purplish and cold, amputation cannot be deferred. It should be a flapless section at the level of the fracture according to Pauchet's method, the upper fragment being roughly smoothed off, subsequent trimming of the stump being necessary. Amputation is less drastic than disarticulation, and is always preferable to it.

In short, the original operation, apart from certain exceptional cases (diffuse arterial hematoma, extensive injuries to soft parts), can generally be limited to prophylactic sub-periosteal esquillectomy.

5. Technique.—Esquillectomy should be performed through a long external and slightly anterior incision ; this incision at the site of election is always preferable to those corresponding to the wounds of entry and exit, which lead to drainage in the vicinity of blood-vessels, or in positions only accessible with difficulty for the purposes of dressing.

When the deep fascia is incised, the edges immediately come together and close the wound, so that there is difficulty in exposing the injury thoroughly with retractors, and there should be no hesitation in making transverse incisions in the fascia lata, so as to produce a widely-open wound, distinctly more extensive than the area of the fracture. After particularly careful cleaning of the soft parts, and removal of foreign bodies, sub-periosteal esquillectomy should be performed on the usual lines. Cleaning of the medullary canal and the cancellous tissue of the upper fragment should not be omitted ; in several cases I have found splinters embedded high up in the cancellous tissue of the trochanter. There should be no fear of operating too drastically : experience shows that surgeons never go to too great lengths, and too easily fail to explore adequately, which accounts for subsequent suppuration. The entry and exit wounds are freed, their internal surfaces being completely excised. The usual aseptic gauze dressing is applied.

The most delicate part of the treatment now arrives, that of immobilisation.

*Immobilisation.*—If possible (*i.e.* unless large numbers of urgent cases are being received, or immediate evacuation is necessary), these cases should always be treated by *continuous extension in a position of marked abduction.* Any fixation appliance not fulfilling these two essential conditions can only be provisional, *e.g.* an appliance for transport; it should not be used for treatment.

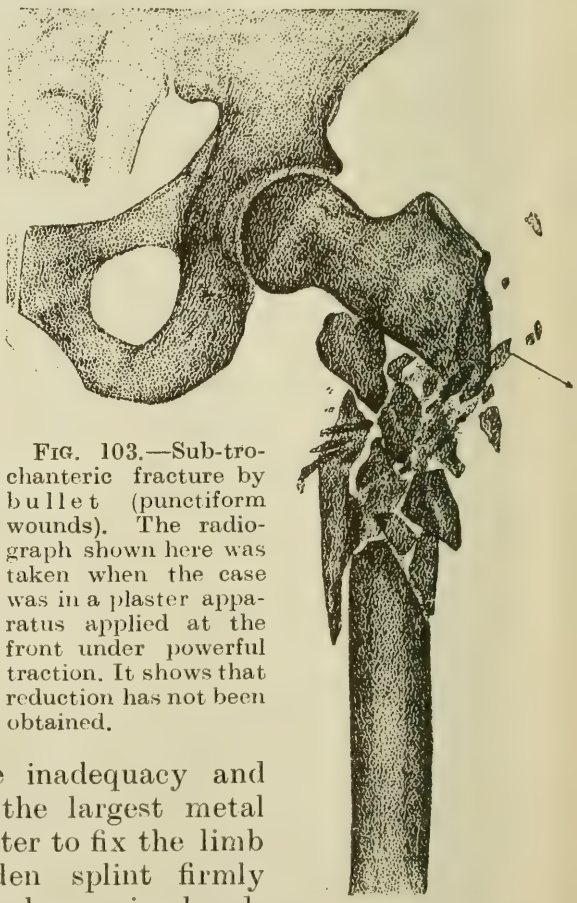


FIG. 103.—Sub-trochanteric fracture by bullet (punctiform wounds). The radiograph shown here was taken when the case was in a plaster apparatus applied at the front under powerful traction. It shows that reduction has not been obtained.

I imagine it is unnecessary to insist on the inadequacy and danger of even the largest metal troughs: it is better to fix the limb on a long wooden splint firmly fixed to the pelvis by a spica bandage. This method of fixation is more complete and less painful.

Plaster, particularly in the form of a pelvi-dorso-pedial splint, immobilises well and diminishes pain, but cannot affect reduction of a displacement; to correct this, even powerful traction under an anæsthetic is

insufficient. In several cases I have seen immobilisation effected by a large plaster well constructed under continuous extension, but in no case was reduction of the displacement obtained (see fig. 103). This should cause no surprise when the magnitude of the muscular forces exerted on the two fragments is considered. There is, however, a more important reason for this failure than the resistance afforded by muscular action; it is the *direction* of the displacement of the trochanteric fragment, over which we have no control. It is therefore necessary to bring the lower fragment into line with the upper, in other words to abduct the thigh to 45° to 50°, according to indications given by a radiograph. The best position cannot always be obtained at once; it is sometimes necessary to feel one's way and to alter the direction of the traction. Under these conditions a permanent rigid appliance, even when applied with the aid of the X-ray screen, is unsuitable, and a rigid appliance is an unsatisfactory means of treating sub-trochanteric fractures. It is excellent for transport and temporary

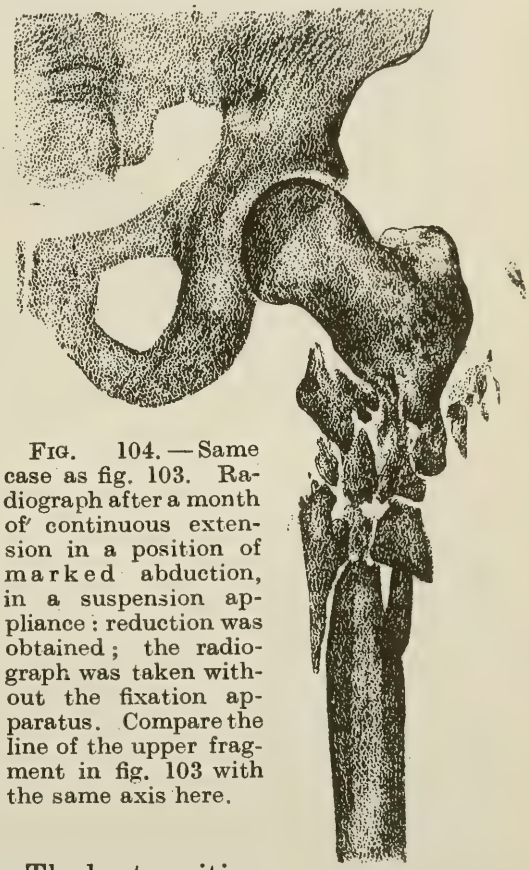


FIG. 104. — Same case as fig. 103. Radiograph after a month of continuous extension in a position of marked abduction, in a suspension appliance: reduction was obtained; the radiograph was taken without the fixation apparatus. Compare the line of the upper fragment in fig. 103 with the same axis here.

fixation, but it is not justified in any other circumstances. Sub-trochanteric fracture should therefore be treated by continuous extension in marked abduction. For this purpose the *suspension apparatus* is the ideal. Details of its construction will be found on p. 527 ; for the present I am dealing only with essential points, and with those which are peculiar to sub-trochanteric fractures.

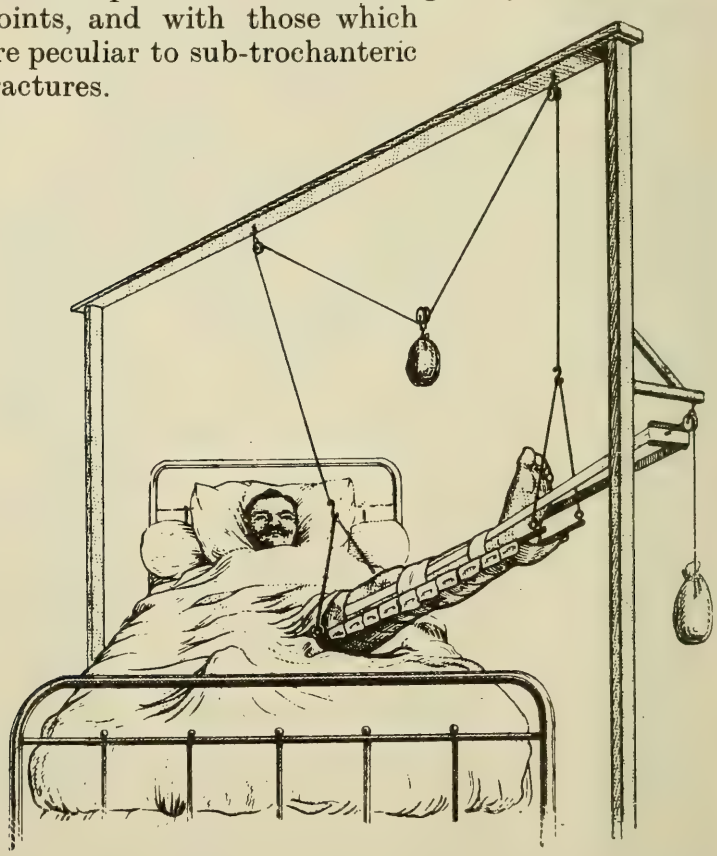


FIG. 105.—Suspension appliance : continuous extension in abduction. Traction of 8 kilogrammes. For the sake of clearness the curved bars connecting the side wires of the splint frame are not represented. Compare with figs. 115 and 117.

Two uprights support a horizontal bar 6 ft. 6 in. above the floor level. The support is placed in the

necessary position, as indicated in fig. 105. It is well to make it of considerable length.

The wire splint frame is suspended from the horizontal bar, and consists of two thin iron rods, about 36 in. long, $\frac{1}{2}$ in. wide, and $\frac{1}{8}$ to $\frac{1}{6}$ in. thick, connected at each extremity by a curved metal bridge, which is bolted to them. Holes are drilled at the ends of the horizontal rods to receive the suspension hooks.

As described on p. 380, lengths of linen are pinned to this frame to form a sling-hammock.

After operation, the limb is placed in this cradle, which is suspended by cords from two pulleys, arranged as shown in fig. 105.

A weight of 4 to 5 kilogrammes is usually required as a counterpoise; this is a weight sufficient to make the splint with the limb in position remain in equilibrium in any desired position. The angle of inclination of the splint may easily be regulated by moving the central pulley supporting the weight.

Continuous traction is exerted in the usual way, *i.e.* by means of a stirrup of adhesive strapping, passing up the limb and fixed, not (as shown in fig. 105, for the sake of clearness) by circular strapping, but by bands wound spirally round the limb. A weight of $3\frac{1}{2}$ kilogrammes is used at first, increasing by 500 grammes daily, until it has reached 7 or 8 kilogrammes.

The right-angled position of the foot is maintained by means of a small padded board, which is strapped within the frame of the cradle.

*Progress after operation.*—Dressing is usually a simple matter, and is performed without disturbing the patient; the wounds being usually clinically aseptic, dressing at long intervals, which is very desirable during the first few weeks, is almost always possible.

As a rule, healing is rapid, and is complete in fifty to sixty days. Sometimes after the fortieth day the patient is under the impression that his limb is solid. I have seen a patient lift the thigh and move it in all

directions at the end of thirty-two days. No reliance, however, should be placed on this apparent proof of solidity; the callus is still soft, and extension and fixation must be kept up for a further long period, or

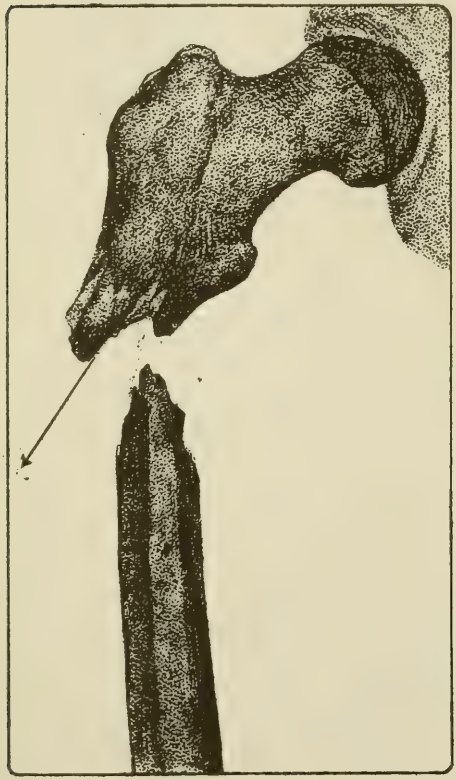


Fig. 106.

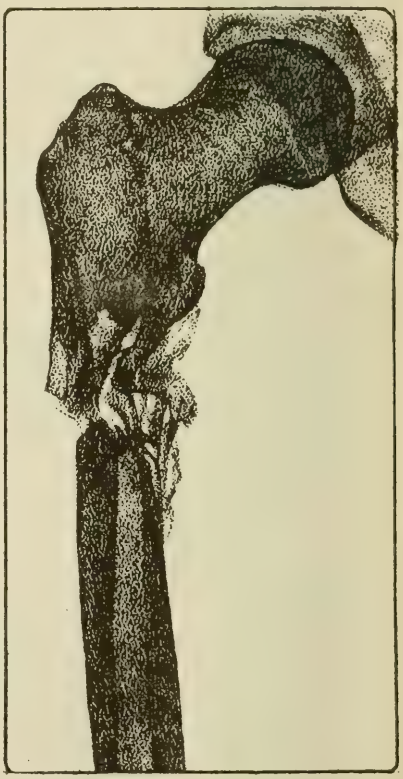


Fig. 107.

Fig. 106.—Sub-trochanteric fracture by a shell-fragment after secondary sub-periosteal esquillectomy (twelfth day).

Fig. 107.—Radiograph on the sixtieth day, showing: (1) reduction by continuous extension in abduction in a suspension appliance, and (2) the periosteal callus, obtained in forty-eight days.

the callus is liable to become bent and give rise to marked angular deformity. This has occurred recently among my own cases (see figs. 107 and 108), and for this reason I emphasise its importance. I consider an

immobilisation of 100 to 120 days necessary. But long before this the limb can usually be restored to its normal position; in about fifty days the callus has a sufficiently firm hold on the upper fragment to influence its position and to maintain reduction if continuous traction is maintained. This should be verified by X-ray examination.

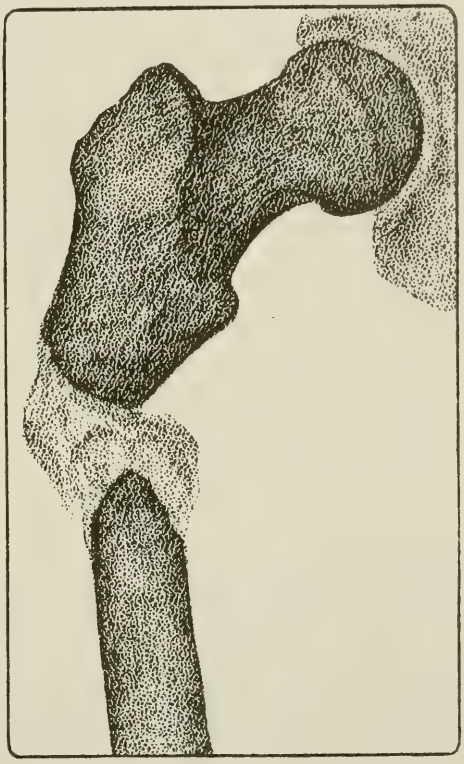


Fig. 108.—Secondary flexion of the callus on the seventy-sixth day, the patient having begun to walk on the seventy-second day. The action of the pelvi-trochanteric muscles has come into play, when the abduction extension was removed. The same apparatus was reapplied and the correction of the deformity was obtained without difficulty, the final result being practically identical with that in fig. 107.

At this stage the patient may with advantage get up, using Delbet's walking appliance, which is described on p. 537.

The results of treatment conducted in this way are excellent: the shortening is not usually more than $\frac{1}{2}$ to $1\frac{1}{4}$ in.; movements of the knee are gradually regained after two or three months of massage and active movements. In short, there is almost complete recovery of function in less than six months, and it is not unusual to see patients able to resume normal

life during the second six months after being wounded.

6. Treatment of cases seen at a later stage, or after previous Treatment.—(*a*) *A case has progressed well without operation.*—The treatment indicated is simply immobilisation, for which purpose the best appliance, as in other cases, is the suspension and traction apparatus described above.

Within a short time, however, Delbet's appliance will be useful, and will allow the treatment to be carried on as long as may be necessary.

It should be remembered that in non-infected comminuted fractures, as for instance those caused by a bullet with punctiform wounds (fig. 103), union, though sometimes very rapid (twenty-eight days in one case in my experience), is often, on the contrary, fairly slow. I have seen a case in which it failed to occur within seven months.

(*b*) *A case that may or may not have been operated upon, arrives in a septic condition.*—The patient may only have been brought in after lying out for a long time (as is frequently the case with seriously wounded and helpless men), and no immediate operation will have been performed. The thigh will be swollen and freely suppurating. Complete sub-periosteal esquillectomy should be performed immediately, as has already been described; there should be extensive removal of muscle, and the smallest bone-splinters should be carefully searched for, and adherent splinters removed, even if they extend for some distance down the shaft. The periosteum, irritated by the infection, will always form a solid column of bone in such cases, and the removal of 3, 4, or 5 inches of the bone may be undertaken without hesitation, if the surgeon will have sufficient patience to separate the periosteum carefully with the gouge. In these cases of secondary esquillectomy, the callus forms very rapidly (I have seen an interfragmentary gap 6 inches wide filled in

this way), as I shall describe in connection with fractures of the shaft proper.

(*c*) *A case is seen at a later stage of infection.*—The outlines of the callus have already appeared, but there is profuse suppuration. It would be extremely rash to undertake a complex operation in a deeply-seated region, which cannot adequately be exposed. Nothing should therefore be done beyond the removal of easily accessible sequestra, and no attempt should be made to clean the infected region completely. The policy is to avoid the spread of infection, and to limit the latter, with the intention of operating afresh when the stage of sinus-formation is reached. After the operation it will be found well to employ warm moist dressings for the first few days.

(*d*) *A case is seen with a sinus.*—A radiograph is absolutely necessary to ascertain the cause of the sinus and determine the treatment. Occasionally the case is found to be one of superficial osteitis, but almost always deep osteitis is responsible, originating frequently from a small sequestrum. In this case, promiscuous curetting is inadvisable, and indeed injurious. The diseased area should be localised very exactly, as a missile is localised, and a methodical search should be made for it, by the shortest route. The operation should always be performed on a comprehensive scale, otherwise there is not much likelihood of getting a good result.

(*e*) *A case is seen with a pseudarthrosis.*—Almost invariably pseudarthrosis is due to lack of reduction, but suppuration has rendered the osseous tissue sterile, and traction combined with wide abduction is not able to bring about union.

A cutting operation is necessary to excise the interfragmentary fibrous tissue, and to bring the fragments into apposition by a metal suture.

If possible, even at the cost of detaching the insertions of the pelvi-trochanteric muscles with a gouge

in order to permit easier movement of the upper fragment, the fracture should be reduced, and the two fragments placed end to end. Unfortunately this ideal can only rarely be realised; muscular and aponeurotic contractures and stiffness of the joint prevent effective action (a difficult matter enough apart from these considerations) on the trochanteric fragment. In a case of this kind I confined myself to fixing the shaft to the lower surface of the upper fragment by a large Lambotte plate. The result was good, in spite of a shortening of 2½ in.; the patient was able to walk again, after a year of absolute helplessness.

(*f*) *Vicious union is found to have occurred.*—There are numerous cases in which the result obtained must be accepted, mediocre though it may be; when, for instance, the radiograph shows an enormous mass of osteitic bone, intervention is very dangerous, and probably destined to complete failure.

If, on the other hand, the radiograph shows lateral union by a callus which is not too dense, and easily accessible, the question of fracture of the callus may be discussed, and of re-immobilisation in full abduction to reduce the deformity. But this decision should not be come to lightly; the operation is always difficult and doubtful in its results, and can only be undertaken in favourable cases.

After osteotomy of the callus involving as little injury as possible, the wound is left open, without suture, and simply plugged with moist gauze; if it is closed, recurrence of infection is to be feared even if drainage is arranged for, and the best means of avoiding all post-operative complications is to keep everything exposed, resisting the temptation to sew the wound up round a large drainage tube.

I am also of opinion that it is better not to correct the faulty position by sudden force, when the callus has been broken, existing conditions are allowed to remain, and continuous extension is exerted with the

lower fragment in its original position, without immediate correction. Progressive abduction to the necessary degree is effected gradually during the days following.

By this procedure in a case of this kind I obtained an excellent result without causing the slightest degree of pyrexia.

## II. Fractures of the Shaft: the so-called Fractures of the Thigh

1. Anatomical Features.—There is extreme diversity of anatomical form in fractures of the thigh. All known types of fracture may be encountered; the most usual is the large-splintered type, more or less resembling the classical "butterfly-wing" fracture. An almost constant feature is the presence of one or two large longitudinal splinters, roughly diamond-shaped, and tapering to sharp points at a great distance from the actual seat of fracture; they often measure 6 inches and more in length, and are adherent by their periosteum to the muscles attached to them.

In the middle of the thigh there is often an internal fragment very adherent to the insertions of the adductors, and when it is separated with the rugine, the impression is produced that the larger part of the bone has been removed; in reality, the splinter amounts only to a narrow strip, the removal of which does not diminish the future solidity of the bone, if the periosteum has been preserved carefully.

Large and small splinters are often forced a great distance into the muscles.

The damage to the muscles is usually very considerable, but it is frequently situated beneath the scarcely lacerated deep fascia. A muscular hernia projects through a small unyielding opening in the fascia, and the wound appears inconsiderable, but if the fascia is opened up, the deep muscles are found

lacerated and destroyed, with areas of interstitial hæmorrhage well beyond the immediately damaged area; their ragged edges come together and form a rigid curtain closing in the region of muscular destruction, in which are splinters, clots, and fragments of the projectile.

Simultaneous injury to vessels or to nerves may occur, but is not common.

I have twice seen an irregular indirect fracture, situated at some distance from the splintered region (fig. 119).

2. Physiological Features.—Owing to the development and strength of the muscles surrounding the femur, there is virtually always displacement of the fragments in fractures of the thigh, and as a rule this is considerable. The forces, which are normally in equilibrium, are arranged in antagonistic groups; fracture destroys the equilibrium, and the fragments are displaced in the direction imposed on them by the group of muscles whose insertions are most completely preserved and whose action therefore inevitably becomes predominant.

There are five principal groups of muscles whose actions are dissociated by fracture:

*The pelvi-trochanteric group*, which acts on the upper third of the shaft, from the trochanter downwards, and causes outward rotation of the thigh, with abduction and slight flexion on the pelvis.

*The adductor group*, which comes into play when the fracture is obliquely directed from above downwards and inwards at the junction of the middle and lower thirds of the shaft; it adducts the upper fragment, slightly flexes it, and rotates it, either outwards or inwards, according to the condition of the lower part of the adductor magnus, which causes inward rotation. If the fracture occurs above this part of the muscle, its action is excluded, and external rotation occurs. This is usually the case, and results in torsion which causes considerable interference with walking, but less

serious trouble than would be caused by an uncorrected displacement in the opposite direction. This external rotation is not surprising, when the posterior plane of the adductor insertion is considered.

*The long posterior muscle group* (biceps, semimembranosus, semitendinosus) which normally flex the leg on the thigh. In fractures situated below the upper third, these contribute to the posterior upward displacement of the lower fragment and of the leg. This upward movement is never direct; there is always slight adduction or abduction due as much to the injury as to muscular action.

*The muscular envelope formed by the quadriceps femoris* which produces vertical upward displacement of the lower fragment.

*The gastrocnemius and soleus* which normally exert no action on the thigh, rotate the lower fragment backwards around the transverse axis of the condyles when the fracture is at the lower end of the bone; this, however, only happens in supra-condylar fractures with which we are not at present concerned.

It results from all this that the following displacements may occur in fractures of the shaft:

Marked *over-riding*, sometimes to the extent of 3 to 4 inches. This is due to posterior displacement upwards of the lower fragment, caused by the muscles surrounding and attached to it, and by the posterior muscles of the thigh arising from the pelvis.

*Lateral displacement* in a direction varying according to the position of the fracture. In fractures, in the upper third of the shaft, the pelvi-trochanteric muscles cause abduction and external rotation of the upper fragment, the lower extremity of which partially penetrates the muscles, and causes a prominence beneath the skin; there is therefore marked angulation, apex outwards, between the two fragments: the curvature which often persists after union arises in this way.

In fractures of the middle, and notably of the lower

third, of the shaft, an opposite displacement occurs: the adductors, whose insertions are generally intact, counteract the action of the pelvi-trochanteric group, or overcome it, and the upper fragment therefore remains in place or is adducted, while the lower is pulled outwards and upwards behind it.

A simultaneous *antero-posterior displacement*, due to flexion of the upper fragment on the pelvis and to slight rotation backward of the lower fragment caused by the calf muscles. As a result of this, the upper fragment is more or less markedly displaced forwards.

*Rotation on the long axis of the bone*, usually external, and principally due to the adductors, and to the weight of the limb.

It is of importance to emphasise the strength of the muscular actions which produce these displacements of the femur; it is such that no manual force can overcome it, and immediate reduction is impossible, even with anæsthesia. It should be remembered that muscular action is more powerful when the limb is extended in a straight line; *if the thigh is flexed on the pelvis and the leg is flexed on the thigh, muscular relaxation is immediate* and correction easier. The surgeon may easily verify this on himself, and after this simple experiment he will easily understand the physiological rules for reducing fractures of the thigh.

It should also be remembered that, as a rule, the contracting muscles carry with them splinters which are thus displaced in unexpected directions; no fracture yields more surprises during an operation than does a fracture of the thigh.

3. Course.—Many cases of comminuted fracture die rapidly from shock and hæmorrhage. The initial hæmorrhage is very alarming; no one who has not seen these cases when they are picked up can have any idea of the loss of blood. The first impression is that a serious vascular lesion exists, but this is generally not the case. Hæmorrhage, however, contributes

largely to the immediate danger in certain cases which do not often pass the first surgical line (*relai*).

Of the less seriously wounded cases which recover from the initial shock, the majority are liable to rapidly developing gas gangrene, diffuse cellulitis, or acute osteomyelitis, and these are fatal if the necessary intervention is not undertaken in time: difficulty in collecting the wounded gives time for infection to develop and greatly favours the severe and often fulminating forms of the latter. Other cases almost always exhibit secondary infection, which may call for the gravest decisions.

Thus the principle of early operation in cases for whom transport is impossible has become a dogma. But it is difficult to do just as much as and not more than is necessary. Superficial cleaning is always insufficient; esquillectomy limited to free fragments only does not prevent the development of acute infections and profuse and persistent suppuration, the outward sign of central osteomyelitis, the results of which are very serious; tracks of pus requiring prolonged drainage destroy the muscles; infection of the fracture area destroys the bone-marrow; finally, the irritated periosteum proliferates rapidly, and encloses diseased or dead fragments, just as the new bone in adolescent osteomyelitis invaginates sequestra (fig. 9, p 303). The periosteal proliferation is almost always adequate to reproduce continuity of the bone, and pseudarthrosis in the shaft of the femur is rare, but a pathological callus is very common.

Moreover, owing to the gravity of the local phenomena of sepsis, and the difficulty of frequent and painful dressings, it is impossible to secure immobilisation in good position during a long period of suppuration; frequently the callus consolidates in a few days, leaving considerable deformity and shortening, and the orthopædic result is bad.

Meantime, the patient is obliged to remain in bed

and the knee becomes stiff and equinus develops; movements of the knee-joint are so limited that there is almost ankylosis, a fibrous ankylosis which will certainly deserve the name unless the condition is much improved by massage and movements.

In short, infected fractures of the thigh, generally because of inadequate esquillectomy, occasionally but rarely recover by the formation of a regular and healthy callus; sometimes the superficial surface of the latter is inflamed, owing to a small sequestrum, and is then easily curable; much more often there are sinuses; there is osteomyelitis, and union is bad; the patients, with muscles atrophied and joints stiff, remain liable to sudden recurrence of infection; the limb is still there, but function, if not completely lost, is at least considerably reduced in value.

4. Indications for early Treatment. (*a*) *Amputation.*—A conservative operation is not always possible in the thigh, and there are conditions in which the necessity for amputation must be recognised. Before sepsis is evident, these indications are not very frequent; they are furnished by the extent of the injuries to soft parts, the extent of injury to the bone, or by the intensity of the shock.

(i) If there is muscular destruction involving half the posterior aspect of the thigh, accompanied by severance of the sciatic nerve, or if the anterior muscles are non-existent over a wide area, amputation is, in my opinion, preferable to any attempt at preservation. Sepsis may be avoided, and its effects would not perhaps be very severe in these widely open wounds; but repair is almost impossible—a repair, that is, compatible with satisfactory function of the limb: the patient would become an invalid, and, what is more, an invalid with a painful wound. Hence a suitable amputation, leaving a stump consisting of such healthy tissue as remains, is often preferable to attempts to preserve the limb.

(ii) If the femur is badly comminuted, *i.e.* practically destroyed for 6 to 8 inches of its length, as is the case in certain wounds of an explosive type, the same remarks apply: the orthopædic result is too doubtful to justify either the trouble involved or the risk that will be run.

(iii) In cases which only rally feebly from their shock, in whom a rapid operation is desirable, and a long one is out of the question, amputation may be necessary to transform a lacerated into a clean dry wound which involves no organic strain during repair; such a procedure makes for safety.

On the contrary, if there is an accompanying vascular lesion (of the femoral artery or vein), a conservative operation should be performed, after ligature of the vessels affected. It goes without saying that ischæmic gangrene of the leg demands immediate amputation.

On the whole, early amputation is only called for exceptionally. It is performed in the usual way, without sutures; the flapless operation should be reserved for infected fractures.

(*b*) *Sub-periosteal Esquillectomy.*—Whenever a conservative operation seems possible, free sub-periosteal clearance is the only means constantly *and under all circumstances* to ensure the regular formation of a healthy callus, combined with clinical asepsis of the wound.

This operation is done, not to carry out an extensive resection of the shaft, but to explore the wound completely and remove anything which blocks it and converts it into a closed cavity, as well as any infecting foreign body, missile, fragments of clothing, free splinters, fragments of dead or devitalised tissue either near or within the bone—everything, in fact, that experience shows is destined to become gangrenous owing to contusion or infection. The interfragmentary gap should be clean, and it should be possible to apply a dressing direct to it without difficulty. In order to

effect this, any adherent splinters that conceal the medullary canal should be removed: if the surgeon knows how to use the rugine with patience, too much cannot be removed, since all elements necessary for repair are left in the wound.

I emphasise these fundamental points because their application is nowhere more necessary or more difficult than in the femur. This difficulty is due to the depth of the injury, to the bulk of the muscles surrounding the bone, and to the resistance of the fasciæ enclosing them, all of which points also explain the gravity of these fractures.

As far as possible, intervention should not be undertaken during the phase of shock; the patient is kept warm, and should receive an intravenous injection of adrenalin (0·5 cc. of a 1 in 1,000 solution) and ·01 gm. of morphine, while favourable developments are awaited. When warmth returns, and the temperature has become normal, and the blood-pressure has risen sufficiently (above 10 by Pachon's appliance) operative disinfection is carried out.

5. Technique.—(*a*) *The Operation.*—The operation is performed under ether or spinal anæsthesia, after

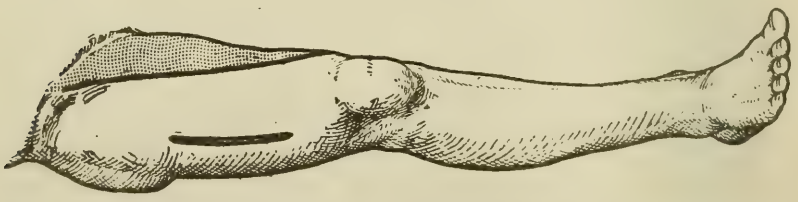


Fig. 109.—The shaded area indicates the region in which intervention should not be undertaken.

X-ray examination and localisation of foreign bodies if possible. The patient should be in a slightly inclined position, with the head low (to counteract the shock and bulbar anæmia).

When the dimensions of the existing wounds do not

absolutely force the surgeon to approach the fracture through one of them, an incision should be made *at the site of election*, that is, on the external aspect of the thigh. *The limb is slightly flexed on the pelvis in order to relax the obstructing muscles. This is of great importance.*

The wounds are first cleaned, and all contused, lacerated, or devitalised parts are widely excised. When the region of the fracture is approached, large retractors are introduced and the wound well exposed and freed completely from any foreign matter. A longitudinal incision is now made at the site of election with clean instruments. The incision should be external, rather than antero-external; anterior incisions are bad, because the scar in the muscles fixes the thigh in extension. The wound should be 4 inches at least in length, and its exact position will vary according to the situation of the wounds already existing. The fascia is incised for the same distance and also nicked transversely, since otherwise its tense edges cannot be separated satisfactorily, and tend to reclose the wound. The vastus externus is incised, bleeding points are tied, and the bone is reached. When the fracture is exposed, two large retractors are introduced, and the injury is examined.

Two conditions may be found: either comminution has occurred, or the fracture is of the long-splinter type.

In the former case, careful clearance with the rugine and forceps is required. Everything entirely free is removed with forceps, then, the wound being clean, the periosteum is separated with the greatest care from splinters which are loose, but still attached to the former. Some surgeons believe that in these cases it is impossible to attempt to preserve the periosteum, and that no one who had ever seen a comminuted fracture would suggest sub-periosteal esquillectomy. Their opinion is worthless, and merely proves that

they are poor operators, lacking in care and patience, and no value should be attached to these ready-made opinions. The fragments situated close to the ends of the shaft should first be located, and their periosteal covering will easily be detected; from this point it will be possible to strip the fragments completely, and when the operation is concluded, there will be the satisfaction of finding a clearly visible channel of periosteum, lacerated, it is true, but forming a resistant whole.

If the splinters are large, after removing those that are free, the periosteum is separated from adherent splinters which require removal, by grasping them firmly with forceps and carefully using the rugine upon them, cutting well down into the bone; this will preserve intact an invaluable periosteal sheath around the end of the shaft.

It is difficult to say exactly how far the removal of adherent splinters should be carried in the pre-infected stage: *it is scarcely ever necessary to remove all of them; it is necessary and sufficient that dressings should be able to be applied direct to the fractured region, after complete exploration of the latter.*

It is therefore an affair of judgment and experience. There is a general tendency not to remove enough, and much determination and experience are necessary to perform a sufficiently comprehensive operation and expose the region thoroughly.

After ligature of every bleeding point and careful cleaning of the whole wound, the gap between the bones, which is now of regular proportions, is loosely packed with aseptic gauze, and the wounds are left unsutured. A counter-incision for drainage is useless; I never make one, even in secondary esquillectomies, and I have never regretted it.

Fractures complicated by vascular lesions require no special treatment, other than the necessary ligature. In wounds complicated by injury to the knee-joint,

which are sometimes seen, missiles within the joint are first removed, the synovial cavity is closed, and the fracture treated independently as though it were the only lesion. Sencert has described a remarkable instance of complete success.

After an operation conducted with the intention of leaving nothing unexplored, the subsequent course of the case is constantly uneventful and aseptic; the dressing may be left untouched for ten, twelve, or fifteen days, and when it is removed, the wounds are found to be of a fine bright red colour. From this point onwards, if time is available for dressing the case daily, the wound may be left exposed to the air for some hours each day, and healing will be accelerated; if the time cannot be spared, dressing at long intervals is continued. With this excellent method I have seen union occur in fractures by the fourth dressing. Generally the patient will be able to lift his limb from the immobilisation apparatus between the fortieth and forty-fifth days. It will, however, be prudent not to allow him to walk alone until a hundred days have elapsed, in order to avoid the disappointment of bending the callus; active movements of the knee may, however, be begun early, and when the patient is finally allowed to get up, walking will be easy, the stage of crutches will be brief; I have seen patients ready for discharge towards the one hundred and twentieth day.

(*b*) *Fixation and continuous extension.*—(1) *The guiding principles.*—After operative disinfection of the fracture, *fixation and continuous extension constitute the two essential objects in treating all fractures of the thigh.* Asepsis demands good fixation; without the latter, continuous trauma infects different parts of the wound and increases the virulence of the organisms present. Continuous extension is the only means of restoring bone and muscle to normal positions, that is of reducing the fracture, which in its turn is the best way of ensuring immediate satisfactory progress, and

at the same time of safeguarding the future function of the limb.

How should these two necessary conditions of treatment be realised ?

Three principles should always underlie it :—

(i) *An immobilisation of the femur is not satisfactory unless the appliance is fixed to the pelvis, or buttressed against the projections of the latter, thereby uniting it with the femur.*

All the trough splints at present in use are thoroughly bad appliances for fixation, and their use should be permanently discontinued.

(ii) *Continuous extension is only satisfactory when the pull is exerted in the axis of the upper fragment.*

The displacement of the upper fragment should be studied in each case, and the extension adapted to it ; when these various displacements are considered (see p. 508), it will be understood that there are fractures in which the pull should be exerted in abduction (high fractures), and others in flexion on the pelvis (fractures of the middle third). There can therefore be no universal apparatus.

(iii) *To avoid useless effort and facilitate extension, the limb should always be placed in a position which naturally neutralises the displacing force :* the ideal realisation of this object is always to arrange the lower limb with the leg slightly flexed on the thigh, and the thigh on the pelvis. In this relaxed position, a much smaller force will effect a more rapid and complete reduction.

These are the general principles on which the treatment of fractures of the thigh should be directed. It is by reference to them that the innumerable appliances suggested for this purpose should be judged,, and above all, it is by such reference that one should be chosen for any particular case. This book is not a general review of the subject, and I shall only describe my own idea of conducting the treatment in the

successive stages of the case, for there is no universal method of fixation and extension applicable everywhere; at each échelon of the Army Medical Service the appliance used should be different and adapted to local conditions. It is only in a base hospital where treatment will be continued until cure is effected that the ideal appliance can be realised.

(2) *The appliances used in the various Echelons.*—(i) *At the Aid-post.*—Temporary fixation should be effected by applying a long, well-padded wooden splint, from the iliac crest down the outside of the limb. This is fixed above by a spica bandage to the pelvis, and also by separate bandages to the knee and leg; a

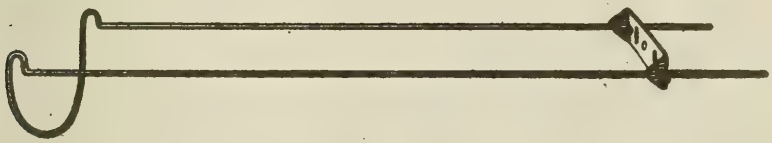


FIG. 110.—Blake's splint.

second splint is applied on the inner side. This rough method is far superior to the metal trough which is no more than a makeshift.

As a matter of fact, the ideal arrangement is the splint recommended by Blake. It is very light, consisting of two iron rods ($\frac{1}{3}$ inch in diameter) united by an oblique curved bar, which takes its purchase beneath the ischium. It can easily be slipped beneath the limb, which is slung in it by strips of bandage; an adjustable foot-rest connecting the lower ends of the side-rods renders it adaptable to all cases.

(ii) *At the Clearing-station.*—After operation, a continuous extension appliance should be chosen, which is not cumbrous, does not interfere with the personal hygiene of the patient, permits ready supervision of the limb, and can be quickly applied. It is also important that it should be possible to keep a stock of these.

If we imagine the working conditions to be those of an active ambulance unit, which is obliged to evacuate operation cases as soon as they can be moved, and not of a unit in a quiet sector, which keeps its cases until they are cured—acting, in fact, like a base hospital—three types of appliance are to be recommended: Sencert's appliance, Blake's splint rest, and the apparatus of Hey Groves.*

I do not include Pierre Delbet's apparatus in this list; it is adapted only for use at the base, and cannot be used in a busy ambulance, because, being difficult to apply, it requires time and careful attention. Moreover, the fact that it permits walking is of no advantage at this stage; for the fractures under consideration, walking appliances should be reserved for convalescent cases at the base.

It may happen that a unit possesses no continuous extension appliance; plaster of Paris is then the only resource. I shall describe the plaster appliance which seems to me best adapted to the circumstances.

(*a*) *Sencert's appliance* (fig. 111) consists of a sort of Hennequin's splint made by cutting to the right length one of those perforated metal sheets supplied to all ambulances. To the sides of this are nailed two wooden slats, the outer being 40 to 44 inches in length, the inner 32 to 34 inches and both 1 inch wide and ½ to ¾ inch thick. The distal ends of these two slats are connected by a thin wooden cross-bar, and by a small rigid iron wire passing through the hole of a cotton reel; in the centre of the appliance another wooden bar is fixed transversely by screws which may easily be removed. A screw hook is fixed in this bar, carrying a wire triangle, through which passes a wide ring of rubber. The latter is simply a circular segment, 2 inches in width, of an old inner tube. Lastly, two

* Schiassi, of Bologna, describes an excellent appliance, in several ways resembling that of Alquier, which deserves to become known; it is very neat, and may be used during transport.

vertical pieces of wood, 7 to 8 inches in length, form a support for the appliance and are fixed at the lower end of the metal trough.

The following is the procedure for applying the apparatus: In the metal splint is placed a towel, and a quantity of cotton wool, in order to pad it well. After esquillectomy and dressing, the foot and leg are firmly bandaged up to the position of the dressing on the thigh. Immediately above the knee is placed a Hennequin's sling, through which the pull is to be exerted. The middle bar of the splint with its rubber

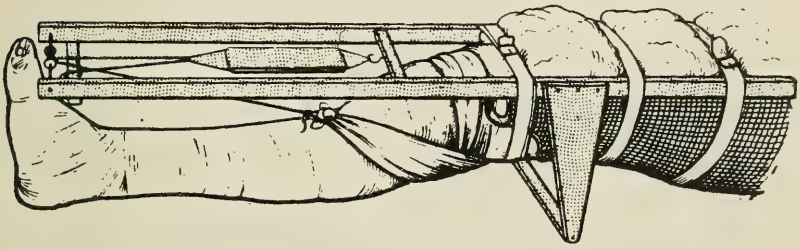


FIG. 111.—Sencert's appliance, which effects continuous extension and allows of transport.

ring is unscrewed, and the thigh is placed in the splint, the inner border of which should be brought up as close as possible to the ischio-pubic ramus, which brings the outer border up as far as the anterior superior iliac spine. The middle bar is then screwed in position. A cord fixed to the loop of the Hennequin sling passes over the reel acting as a pulley, and is fixed to the india-rubber ring, which is previously stretched: continuous traction is thus effected. Finally, a small wooden splint is applied to the anterior aspect of the thigh, which is intended to prevent antero-posterior displacement, and the towel originally placed in the trough is folded over the dressing. Three straps are used to keep the whole in position.

This appliance effects perfect extension, easily reducing the greatest displacements; further, it pro-

duces very effective immobilisation, and is satisfactory for long-distance transport. I have used it, and obtained excellent results. It has only one disadvantage: it cannot reduce the anterior displacement in fractures in which the upper fragment is directed forwards. In these cases an appliance is required which flexes the thigh on the pelvis. The surgeon may be satisfied with provisionally exercising direct pressure by a small wooden splint, as suggested by Sencert, but this should only be temporary; better results can be obtained with other appliances.

($\beta$) *Blake's splint*, described above (fig. 110), is much to be recommended: it is convenient in use and the reverse of cumbersome, easy to apply, and an ideal appliance for ambulance work.

When it is applied to the limb, the latter may easily be suspended from the roof of an ambulance car by cords and a spring; it thus constitutes a treatment and a transport appliance at the same time.

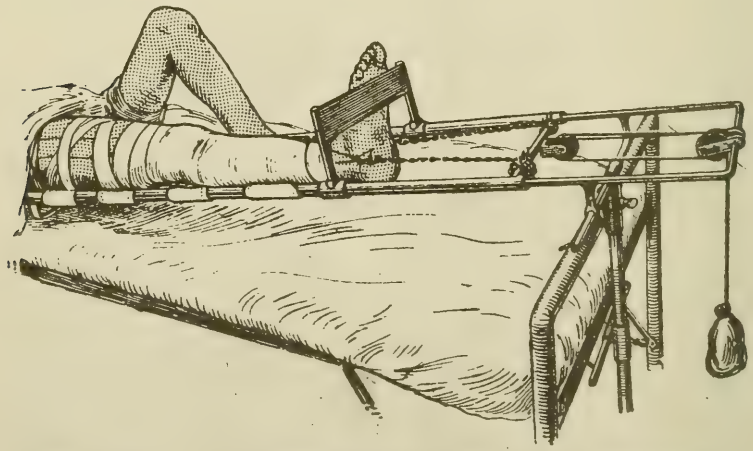


Fig. 112.—G. W. Hawley's continuous extension apparatus.

It may be modified to resemble G. W. Hawley's appliance, shown in fig. 112, which appears equally excellent.

(γ) *Hey Groves's splint* (fig. 113) is purely an appliance for treatment, but its convenience and real advantages should bring it into general use in surgical ambulances. Its object is to effect immobilisation by suspension with continuous extension by simple means, thus obviating the use of the cumbrous suspension appliances which render immobilisation by suspension difficult at the front.

By means of steel rods, ½ inch in section, two inclined planes of unequal length are constructed. The ex-

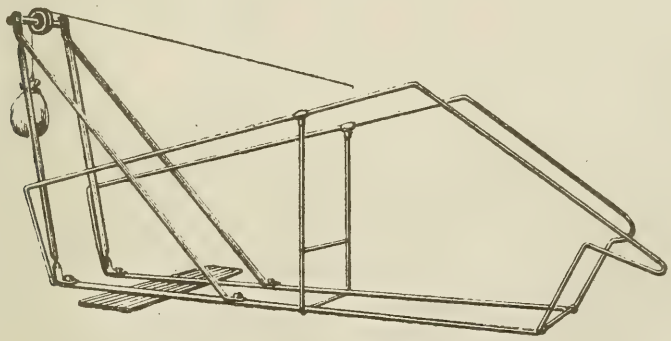


FIG. 113.—The Hey Groves apparatus.

tremities of the two rods are bent back and fixed to a steel frame.

A transverse metal plate ensures rigidity and serves as a fixation point for the vertical branches of the extension support. The suspension sling is made as usual with flannel bands. Hey Groves also recommends strips of rubber (pneumatic tyre inner tube) in the parts opposite the wounds, their elasticity acting as a counter-extension. The sling is padded, and the limb placed in it, with the knee opposite the angle between the two inclined planes, both knee and hip-joints being flexed; extension is applied above the knee in the usual way, the traction cord passing over a pulley (fig. 113). Steady traction on the thigh should be maintained while the appliance is being fitted.

This appliance has numerous advantages: it is not cumbersome; an ambulance unit can keep a large stock of them, the frames fitting one into the other; they are easily cleaned, even sterilised; they rapidly exert continuous extension in flexion, which is ideal in the majority of cases, counter-extension being effected by the weight of the limb; dressing and X-ray examination is easy, and painless transport is possible.

(δ) *Plaster appliances.*—All kinds of circumstances necessitate the use of plaster, *but a plaster appliance should never be anything but temporary*, to be replaced as soon as possible by a continuous extension appliance, leaving the limb freely exposed to the air. Undoubtedly, numerous forms of plaster appliance have been suggested, which effect continuous extension by means of lacing, or of shafts and springs resembling those in Delbet's appliance, but these are only mediocre appliances, whose application occupies a great deal of time, and whose therapeutic effect is decidedly inadequate, because within a short time their immobilisation is no longer good, because they imprison the tissues, and because they do not afford the choice of a good position for traction. I need not emphasise this last disadvantage after what I have written above on the point.

Granted that they cannot be used for treatment, plaster appliances should be as simple as possible: their sole object is to afford a good fixation until the apparatus best suited to the case can be applied; for this purpose the best plaster is the dorsal pelvi-pedial rest, described in Part I, p. 195, for post-operative immobilisation after resection of the hip (see figs. 62 and 63, Part I).

It consists of two plastered portions forming a T with unequal branches: the pelvic limb covers the antero-lateral part of the pelvis, being applied over the iliac crests and the hips; the other is moulded as a trough on the anterior aspect of the thigh, leg, and foot,

and the limb is as it were suspended by a roller bandage fixing it.

Bosquette has very successfully modified this splint by maintaining rigidity in the region of the thigh simply by two strips of sheet iron, with the result that the wounded region is freely exposed, being merely crossed by these narrow connections, which do not interfere with dressing, and, being reinforced, are very resistant. The diagram below (fig. 114) shows the

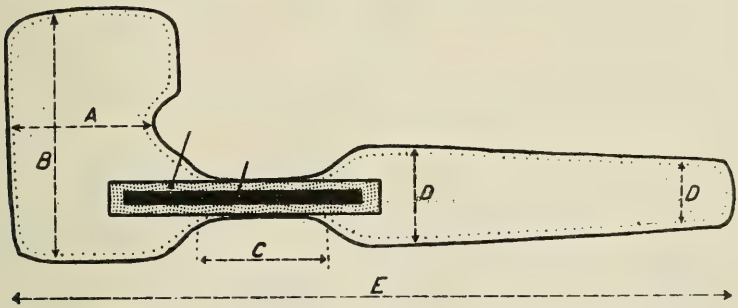



FIG. 114.—Dorsal pelvi-pedial plaster support, with reinforcing sheet-iron slats (Bosquette's model). (A) Distance from the pubis to the xiphoid cartilage; (B) Semi-circumference of the trunk at the level of the umbilicus, increased by 8 in.; (C) Length of thigh occupied by the dressing; (D) Semi-circumference of the limb; (E) Total length, from the level of the xiphoid cartilage to the base of the toes, following the curvatures of the limb. The appliance consists of twenty thicknesses of tarlatan, and the reinforcing slips ten thicknesses; the dotted lines indicate the seams. Only one connecting slat is shown, and the reinforcing support. The apparatus usually consists of two slats and three supports.

exact construction. I have several times received cases immobilised in this way: they had had no pain during transport, and the fragments were kept rigidly in position, without, however, being completely reduced. *This easily constructed apparatus seems to me the best existing type of plaster appliance for the first few days, and for transport.*

(3) *For transport*, no form of trough should be used; they are painful, and the injury is increased by continuous trauma: their supply to the Medical Service

should be stopped. In place of them, one of the following may be used: Sencert's appliance, Blake's splint, or Bosquette's type of the dorsal pelvi-pedial plaster.

(4) *At the base hospital*, after dressing. X-ray examination, and slight further operation if necessary, when the direction of the displacement has been

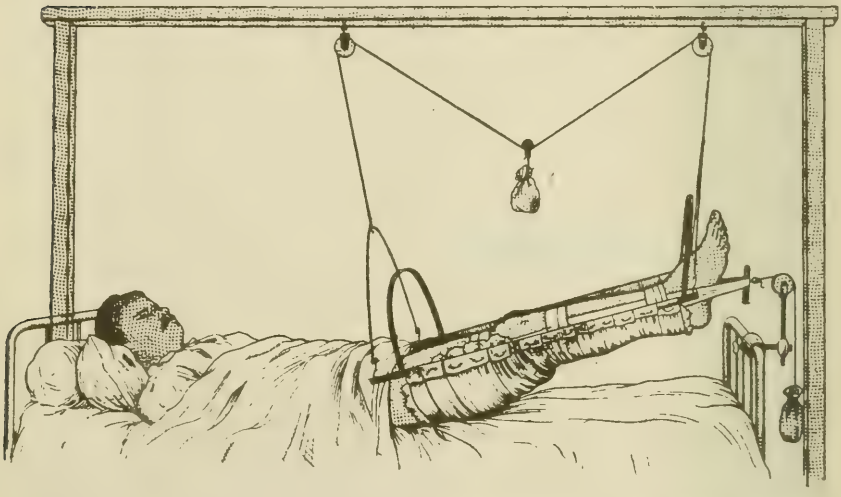


FIG. 115.—Suspension apparatus for fracture of the thigh, much simplified and easily improvised.

determined, the final apparatus should be applied as soon as possible.

Three can be recommended: a suspension appliance, Pierre Delbet's apparatus, and Alquier's appliance.

*I consider the suspension appliance to be the best of these:*

Because it allows of continuous extension in any position whatever, according to the requirements of each individual case.

Because it does not prevent careful supervision of the wounds and of the entire limb.

Because it allows of the maximum possible exposure

to the air or the sun, and does not closely confine the muscles and joints.

Because it greatly facilitates personal hygiene in that it is possible for the patient to move and lift himself with ease and without pain.

(1) *Suspension appliance with continuous extension.* —(i) *The Appliance.*—This is the Balkan apparatus

FIG. 116.—Frame for suspension splint.

still referred to as American, although its principle is apparently French. It comprises :

A frame of the type described on p. 500 and shown in fig. 38, or the overhead bar (fig. 115), which is very satisfactory in use.

A frame fitted as a sling with bands of linen. I

FIG. 117.—A very simple model of the metal splint necessary for the construction of a suspension hammock ; this model is the best.

have used many kinds of frames : one of deal with a support curved like the back of an arm-chair for the pelvic part (this is the simplest model, and easily

improvised anywhere); a metal frame constructed on the type of Blake's, the outer border extending from the anterior superior iliac spine to 2½ inches beyond the heel, and the inner border from the pubes to 2½ inches beyond the heel, 6 inches wide at the foot, and 14 inches wide at the groin (fig. 110); the frame used by Tuffier, the form of which is shown in fig 116; the double metal splint shown in fig. 117 and also in fig 105. All of these have given me the same good results, but the last of the models shown is certainly the most practical, on account of the two connecting arches, which can be used, the lower for fixing the foot, and the upper for drawing the appliance backwards, maintaining its position, and preventing slipping.

When possible, however, a *jointed splint* should be used, as shown in fig. 118. This allows of flexion of the leg on the thigh *; a screw joint and curved guides on each side make it possible for the leg to be placed in any degree of flexion desired.

The suspension sling is completed by strips of bandage; at the level of the wound this material is replaced by a double sterile towel, one enveloping the dressing, and the other acting as a sling. The four hooks are intended for suspension of the apparatus in the usual arrangement (fig. 115).

The weight necessary for counterpoising a thigh varies from 4 to 5 kilogrammes, according to the weight of the limb and the amount of friction in the pulleys.

(ii) *Continuous extension.*—I have always employed traction by bands of strapping, applied as in the classical type of extension (Tillaux). If this is to be well tolerated, the limb must first be shaved and washed with ether; the crural extremities of the two

* Soubbotitch recently described an ingenious and simple appliance facilitating treatment in the flexed position (*Académie de Médecine*, Oct. 24th, 1916). The original feature of his metal rest is a joint which allows automatic lengthening of the femoral inclined plane between the tuberosity of the ischium and the popliteal space, thus adapting itself to the increased length of the thigh in extension.

parallel bands must be divided into strips, which cross each other ; instead of using circular strips of strapping to fix the parallel bands in position, a spiral strip should be applied from the malleoli to above the knee.

If the pull is to be exerted with the limb flexed, the imbrication on the thigh should be very precise, and a few circular bands will be necessary for fixation ; the lowest of these should be sufficiently far from the

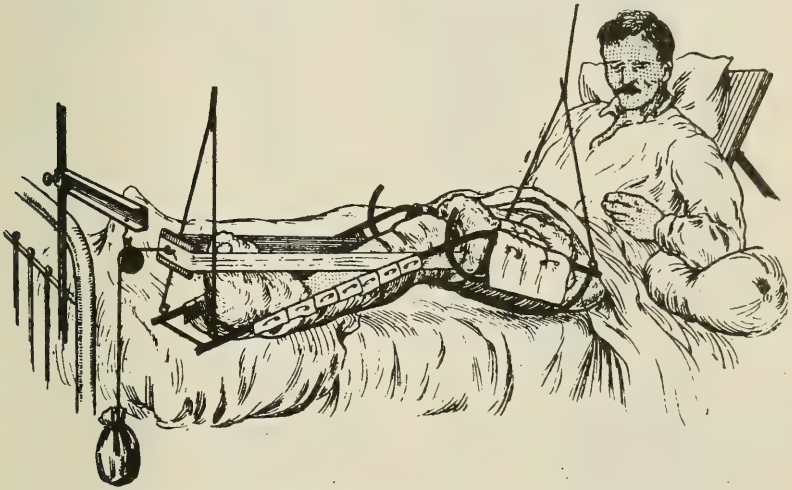


FIG. 118.—Jointed splint permitting treatment by flexion at the knee and hip joints. When the patient represented here was lying down, the thigh was flexed to 45° on the pelvis.

patella not to come in contact with it, as this is very painful. As the weight required for extension is much greater in flexion than in extension, traction may also be exerted through bands of strapping placed over a dressing surrounding the knee.

Certain patients do not tolerate traction well ; the bands take the skin off, and in a short time cannot be endured ; under these conditions, the Finochietto stirrup as employed by Chutro * appears very suitable

* Heitz Boyer has recently modified it by the addition of a flanged aluminium foot-piece and a transverse spring, which ensures a good position of the foot in flexion or extension on the leg under all circumstances (*Société de Chirurgie*, October 25th, 1916).

(see fig. 33), if the pull is to be exerted in extension. I have no personal experience of it.

(iii) *Choice of position for extension.*—This is decided by clinical examination

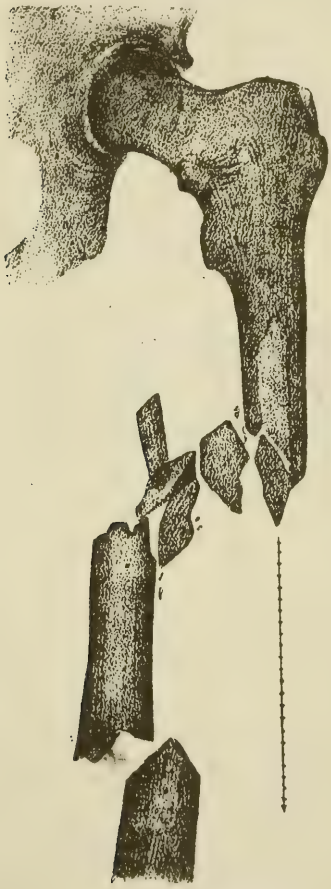


FIG. 119.—Double fracture of the thigh, seriously infected, treated at the front by simple drainage of the soft parts; radiograph on arrival under my care on the eighth day. My first idea was to amputate.

FIG. 120.—Radiograph one month later: complete subperiosteal esquillectomy. The periosteum is already very apparent; continuous extension has brought the lower fragments well downwards, but reduction is not, however, sufficient, as the upper fragment is projecting forwards.

and radiographs taken from both aspects. In a general way, traction with the limb flexed on the pelvis (30°)

FIG. 121.—Third radiograph, one month after the former. The limb has been placed in a suspension appliance, in an almost vertical position, at first in line with the trunk, then in abduction. The anterior displacement of the upper fragment was thus almost completely corrected, and the intermediate fragment carried outwards, but abduction has had an unfortunate effect on the upper fragment.

FIG. 122.—Fourth radiograph at the end of the fourth month, traction of 7 kilos having been applied, in line with the trunk, and with flexion to 45°, in a suspension appliance. The reduction is now very satisfactory.

in marked abduction (45° to 50°) is suitable in fractures of the upper part of the bone; in fractures of

the middle, traction with the knee extended, but with more or less pronounced flexion of the thigh on the pelvis (30° to 80°); in fractures of the lower part, traction with slight flexion of the thigh, and flexion of the leg to about 30°.

But there is an optimum position for each individual case; slight abduction is often necessary for fractures of the middle part of the bone, or slight flexion of the leg to counteract the backward rotation of the lower fragment; sometimes it is necessary to place the thigh almost at a right angle to the trunk. In a case, radiographs of which are reproduced (figs. 119, 120, 121, and 122), I was obliged to alter the position of the thigh several times to effect reduction: traction was first applied with the thigh flexed to 85° on the pelvis, in order to correct a forward projection of the upper fragment; then it was applied in adduction with the object of bringing the intermediate fragment into line; finally, the limb was brought straight again. The radiographs show the successive stages of this treatment and the result obtained. These successive and necessary stages would have been impossible with any ordinary appliance.

(iv) *Fitting the apparatus.*—When placing the limb in the splint, an assistant should make firm traction on the thigh and the leg, so that pain may be avoided and nothing may move in the region of the fracture, which is further supported by two hands beneath it. The splint is prepared beforehand and is slipped under the limb and passed as far upwards as possible so that it takes purchase from the pelvis: this is essential.

Traction is immediately made by the weight estimated to be necessary; a weight of 3 kilogrammes is used at first, and increased each day by 500 grammes, until 7 to 8 kilogrammes is being used: this extending force will generally effect axial reduction. If a double inclined plane is used, 4 kilogrammes is often sufficient.

The suspension cords are then fixed to the hooks,

and the counterpoising weight placed in position : this should be about 4 to 5 kilogrammes ; the weight must be sufficient to suspend the splint and the limb just off the bed, with the limb slightly flexed on the pelvis. If there is pain, the weight is increased and the position of the median pulley on the cord shifted until a painless equilibrium is obtained, and then the position of the traction pulley should be finally fixed. The steps of the procedure cannot be definitely described ; only one rule can be given : in proportion as the patient suffers, the position is bad. When the appliance is in good equilibrium, all movements of the limb as a whole are possible and not painful.

The sterilised sheets are then applied beneath the splint, and the whole apparatus is enveloped in a small covering of sterilised wool, in order to keep the limb warm. A small pad of cotton wool may also be placed between two layers of gauze and the foot covered with it.

As is always the case when the lower limb is immobilised, the mattress should be firm, and made resistant by slipping fracture boards beneath it : this is the classical procedure.

(v) *Care of the foot.*—The position of the foot should be examined every day in order to prevent the development of a troublesome pes equinus. The patient should be advised to practise frequent movements of flexion and extension, in order to avoid stiffness of the tibio-tarsal joint. For greater safety, if necessary, the foot should be kept at right angles by means of a flannel bandage fastened to the lower curved metal arch of the splint, or by means of a small pasteboard or aluminium foot-piece attached to the sole.

(vi) *Method of dressing.*—In fractures in which the operation has been performed at an early stage, and subsequently remains clinically aseptic, dressing at long intervals is an excellent thing. If the wounds suppurate, I expose them each day to the air, if not

to the sun. For this purpose, or at least for dressing, the counterpoise weight is pulled down in order to raise the limb higher above the bed, the slings of the splint corresponding to the wound are unfastened, the dressing is removed, and a sterile towel is immediately folded and placed beneath the thigh, with its edges folded over the metal frame of the splint. Dressing is usually very simple after esquillectomy. Figs.

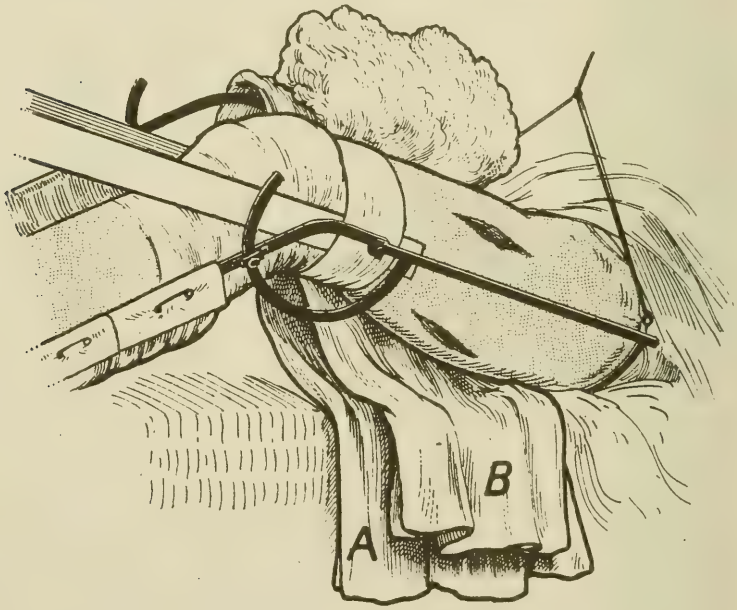



FIG. 123.

123, 124, and 125 are the best description of the suitable way of performing it.

(vii) *Possible complications.*—Apart from the trouble sometimes caused by the continuous extension bands, which offers much scope for the personal ingenuity of nurses, I know of only two possible complications—œdema of the leg and foot when traction is exerted with the knee flexed, and œdematous swelling of the lips of the wound.

Œdema of the leg is due to venous compression in the popliteal space; it can be made to disappear by altering the angle of flexion, removing the garter suspension band, or exerting the pull for some time with the knee extended.

An œdematous condition of the wound is the first sign of a slight deep infection, due sometimes to negligence in dressing, but almost always preliminary

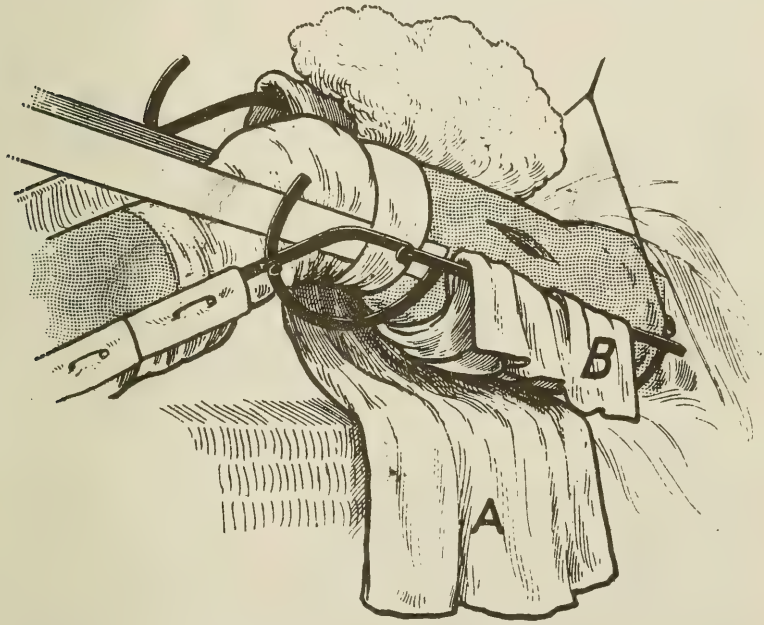



Fig. 124.

to the elimination of a sequestrum. Sometimes, but only after esquillectomy performed during the febrile state (it happens, in fact, towards the end of the second month), one of the extremities of the shaft becomes necrosed; a radiograph and exploration of the wound with forceps will detect the sequestrum and succeed easily in clearing up this slight complication. If necessary, the patient may be anæsthetised with

ethyl-chloride, and the cause of the trouble investigated in any suitable way.

(viii) *Duration of immobilisation.*—The progress of the fracture should be followed by radiographs. Unfortunately the suspension apparatus cannot be transferred with the patient to the X-ray room, but the extension may be easily removed, the suspension cords detached, and the limb carried in the splint.

As a rule, periosteal proliferation is visible in a good

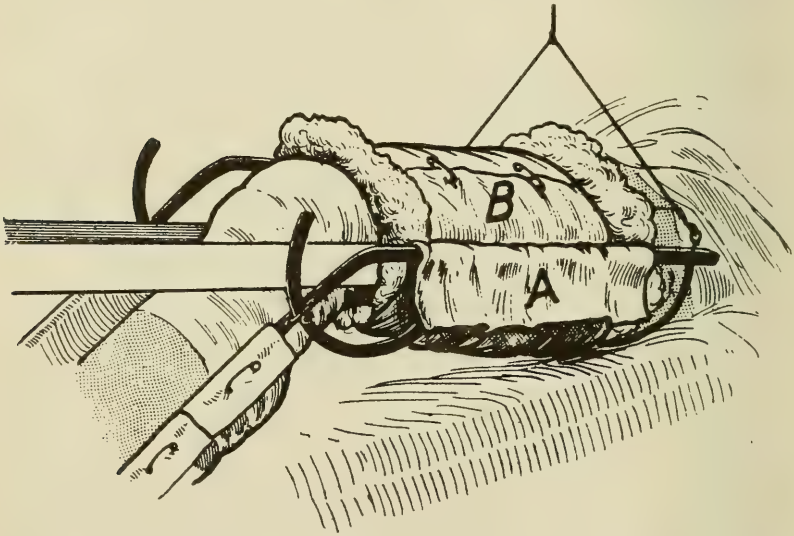



FIG. 125.

X-ray plate in the form of a more or less obvious shadow at the end of three weeks. At this stage the deep surface of the wound is granulating, and of a bright red colour, and is firm and regular to the touch.

At the end of six weeks the ossification is clearly outlined in the radiograph, usually on the side opposite to that of the surgical wound. Some patients are able, from this point onwards, to support the limb if it is lifted, but without always being able to raise the heel from the bed unaided. Subsequently the union becomes definite, and usually towards the end of the

second month, when healing is complete the clinical impression is that of a firm callus.

In young subjects, continuous extension may be permanently discontinued at this point. In the case of older men, it is wise to continue it for a few weeks (until the hundredth day) in order to avoid secondary curvature.

Owing to the necessity for prolonged extension, it would seem advisable to use Delbet's appliance from the third month onwards.

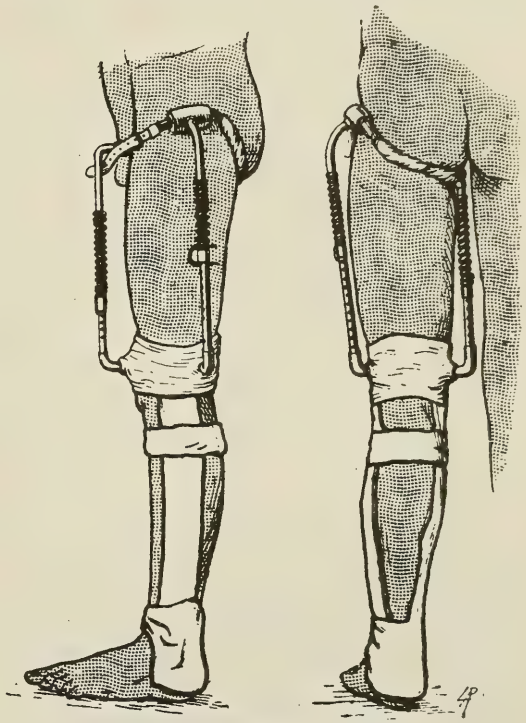


FIG. 126.—Pierre Delbet's apparatus.

(2) *Delbet's appliance.* — The object of this apparatus is to allow the patient to leave his bed and walk at an early stage. It consists of a metal pelvic ring specially curved which takes purchase against the ischium and the ischio-pubic ramus, and three spring extension shafts fixed below to a plaster collar moulded round the condyles. Of these three shafts, one is internal, one anterior, and the third, which is longer, ends in a hollow cylinder supported against the trochanter.

The accompanying fig. 126 explains the construction of the appliance.

The following are required for fixing it in position: an ordinary plaster bandage 2½ inches wide and 6 yards long, and a band consisting of twelve thicknesses of starched tarlatan 3 fingers in width and a yard long. This is split at each extremity along the median line and almost to its centre; in this way a four-tailed band is produced, which is intended to surround the lower part of the metal appliance on the thigh.

The appliance is fitted in the following stages:

Construction of a supra-condylar plaster ring, gripping the femoral condyles.

Padding of the pelvic ring.

Placing the pelvic ring in position, the supports, springs, and pins having been removed, but with the strap attached. It is placed on the inner side of the thigh, with its concavity facing upwards and outwards. The hand is slipped under the thigh, and, by means of the strap, brings the posterior part of the ring beneath the thigh, while the other hand applies it to the genito-crural fold.

Fitting of the strap, springs, and crutch-supports.

Application of the four-tailed band beneath the plaster collar.

Construction of a Delbet walking leg-appliance (see p. 564), which is fastened by means of a Scultet apparatus.*

When all is in position, time is allowed for the plaster to dry, and tension of the springs is brought into play, the internal spring being powerfully compressed, the external less, and the anterior very little.

During the following days the tension is modified so as to effect a progressive reduction, and when this has been obtained, the apparatus is fixed in

* Scultet's apparatus is a kind of many-tailed bandage, the ends of which are rolled round a cane on each side. The tails are brought together round the limb over the plaster in order to mould the latter to the contour of the limb and the apparatus is subsequently removed. For further particulars see Delbet, *Le Traitement des Fractures*. (Paris, 1916, p. 90.)—EDITOR.

position with split pins, and the patient allowed to get up.

The degree of tension of the springs and the condition of the skin in the genito-crural region require frequent attention.

At the end of about fifty days the leg-plaster may be removed. The rest of the appliance is kept on for at least two months.

This appliance has great advantages, which are recognised by all who have used it : it reduces well, allows the patient to get up at an early stage, and ensures a good ultimate result. It possesses the disadvantage of being difficult to apply well.

I believe that its use is particularly advisable during the period of convalescence, which it shortens considerably. I have only employed it in this late stage, and have no experience of its use in the earlier stages.

(3) *Alquier's appliance.*—By making use of certain parts of Delbet's appliance, Alquier has constructed an

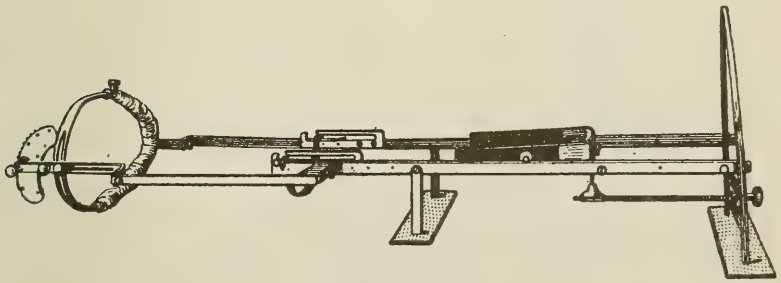


Fig. 127.—Alquier's apparatus.

original apparatus, the excellent results of which I have seen at the hospital at Châlons, but which I have never actually employed. It has been described by Foisy, whose account is reproduced here :

It is a combination of a mechanical and a plaster apparatus. The mechanical part consists of five principal pieces : an upper collar, a pedestal-support, two lateral bars, and a traction appliance.

The upper collar is of metal, consisting of two parts, an internal ischio-pubic piece curved exactly as in Delbet's appliance, and another, external, jointed to the former behind, and also attached to it in front in the region of Poupart's ligament. A screw unites the two pieces firmly.

The semicircular pedestal-support has a large flat base, which acts as a support. A perforated transverse bar is fitted to the former, through which passes an extension screw.

The lateral bars are composed of four pieces, allowing adjustment according to the length of the limb and the width of the thigh. The inner bar is fixed at one end to the collar, and at the other to the pedestal, but the upper end of the outer bar slides in the collar, and ends in a crescentic pad which can be adjusted vertically and transversely, and takes purchase against the outer surface of the ilium; its lower end is fixed to the pedestal. The two lateral bars are supported about their middle by an extra pedestal-rest.

The traction appliance consists of a semicircular condylar collar ending in two wings sliding on the lateral bars, and a stirrup sliding in the same way.

The leg, knee, and popliteal space are padded, and a plaster apparatus is applied consisting of a collar moulded on the condyles, as in Delbet's appliance, and a plaster splinting extending from the lower part of the condylar collar to the base of the toes.

In fitting the apparatus, the upper collar is first placed in position,* and the limb is slung between the two lateral supports. When the upper collar has been secured, the external pad is fixed above the great trochanter, the collar is applied closely to the depression immediately above the condyles, and fixed there by means of a plaster bandage. Lastly, a stirrup is secured above the malleoli by means of another plaster bandage.

* Heitz Boyer has recently rendered the appliance more easily applicable, by making the external support movable.

When the plaster is dry, traction is gently and progressively applied so as to reduce the fracture in a few days.

6. THE TREATMENT OF CASES FIRST SEEN AT A LATER STAGE OR AFTER PREVIOUS TREATMENT—(*a*) *A case is progressing well after several days.*—After radiography and study of the displacement, the limb should be placed under continuous extension in a suspension apparatus. Early use of Delbet's appliance is also possible.

Operation is obviously unnecessary.

(*b*) *A case is seen with pronounced local sepsis.*—Whether the region has already been cleared or not, immediate sub-periosteal esquillectomy and drainage is indicated. After radiography, a radical operation is undertaken through an external incision: the soft parts are carefully cleaned with scissors, and a minute search is made for free splinters embedded in the muscles. When the region of the bone is reached, extensive esquillectomy is effected with the rugine. *I am more and more convinced that in the secondary period, sub-periosteal esquillectomy should be complete, bearing in mind the vital activity of the periosteum when irritated by the infection* (see figs. 24 and 25, p 329). The medullary canal is scraped, gently and not excessively. Finally, the wound is packed with gauze moistened in hypertonic saline, and the limb is immediately placed in a suspension apparatus.

FIG. 128. — Bad comminuted fracture with numerous shell-fragments *in situ*.

The dressing should be renewed in forty-eight hours. After examination of the wound, and, if necessary,

completion of the mechanical cleaning by excision of any torn and gangrenous tissue, a fresh dressing moistened with saline is applied.

In five or six days the wound will generally be clean, the temperature normal, and the course of the case will be uneventful; dry aseptic dressings may then be used.

Elimination of a sequestrum from the ends of the

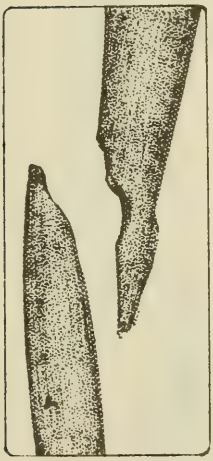


FIG. 129.

FIG. 130.

FIG. 131.

FIG. 129.—Radiograph on the fifteenth day after total subperiosteal esquillectomy (same case as fig. 128).

FIG. 130.—Radiograph at the end of four weeks, treatment being by continuous extension.

FIG. 131.—Radiograph at the end of five months: the wound healed in two months, and union occurred at approximately the same time. There is a shortening, measured several times, of $\frac{1}{2}$ inch. On the other hand, there is rather marked stiffness of the knee.

shaft may occur during the course of the second month. This is preceded by slight œdema of the edges of the wound, and a small amount of suppuration: a radiograph should be taken, and the sequestrum should be located and removed with forceps. This is usually easy, and is followed by immediate disappearance of the symp-

toms. The procedure materially shortens the duration of treatment, and prevents the formation of a sinus.

Continuous extension should be prolonged in proportion to the age of the patient and the extent of the original esquillectomy; walking should not be permitted until three months have elapsed. I have often seen union occur between the thirty-second and fortieth day, and one patient got up at the end of forty-five days, but this is not an example to be followed.

(*c*) *A case is seen after prolonged suppuration.*—In a case arriving after a month or more of treatment, with considerable suppuration and daily rise and fall of temperature, treatment is a difficult matter. Complete esquillectomy and drainage are no longer possible, since a considerable extent of the bone is diseased, and inopportune trauma would provoke an acute infection the gravity and results of which it is impossible to calculate.

Only what is strictly necessary should therefore be carried out—freer drainage of the soft parts, removal of easily accessible sequestra without interfering with any that are adherent, the opening of abscesses, and a patient watch for developments. The temperature will often become normal and the general condition improve as a result of such simple interference, but an operation on the bone itself will always ultimately be necessary. Previous to this, and after all minor interventions, a warm moist dressing is very effective in reducing the phenomena of sepsis.

If the situation has not distinctly improved after some days, amputation must sometimes be considered. Too frequently days pass in hesitation and delay, and the amputation is performed too late to combat the effects of chronic septicæmia. In these cases I usually perform a circular amputation, leaving a flap of skin of greater length than is necessary, which is well retracted; the muscles are cut in one transverse sweep, and the flap is left turned back on the skin. This

gives complete exposure of the area and is very favourable for the immediate arrest of septic conditions.

Sometimes high temperature persists after the amputation, and the situation is then one of anxiety : under such circumstances I have found it well to employ a large warm bath (102° F.), in which the patient remains for two hours. After the bath, I have seen a regular fall of temperature by lysis, and great improvement in the general condition, the patient being very soon out of danger.

(*d*) *A case is seen with a sinus.*—There is no region where a bone sinus is more difficult to cure, when esquillectomy has not been performed. Cases certainly occur, in which the sinus is simply evidence of slight superficial osteitis, but more often it leads to a septic cavity or to a deeply imprisoned sequestrum. The lardaceous and rigid muscles form a troublesome obstacle to any attempt at exposing the bone, and prevent exposure of the region and free drainage.

After a precise conception of the situation and extent of the lesions has been formed from a radiograph, there should be no fear of too comprehensive an operation, or hesitation in deliberately sacrificing sclerosed muscular tissue which can never function : it is useless, and extremely inconvenient.

(i) *If there is an osseous cavity*, one side of it must be removed, and the edges bevelled, that is to say, it must be thoroughly exposed as far as this is possible : this is an essential condition for cure. When the cavity has been well disinfected by exposure to the air, by hot air, and particularly by the sun, it may be plugged with Mosetig's iodoform mixture, or with bismuth in the form of Beck's paste, which will perceptibly shorten the duration of treatment. I do not mean that secondary suture should be done after the plugging, although this is perhaps often possible, but it seems scarcely wise without bacteriological examination ; the only object of the plugging is to facilitate oblitera-

tion of the cavity with newly-formed tissue. After plugging, I leave the wound open to the air during the day; during the night, the dressing is a simple sheet of gauze for purposes of protection. It has seemed to me that healing is markedly accelerated by this procedure.

(ii) *If a sequestrum is present*, it should be cut down upon, however large an incision may be necessary for the purpose.

Here, more than anywhere else, random scraping should be avoided.

(*e*) *When union has occurred with marked shortening.*—With a shortening of less than 1¼ in. there is virtually no lameness. With a shortening of 2½ in. the patient walks lame, but is not seriously inconvenienced; it is enough to wear a thick sole. As a matter of fact, shortening cannot be referred to as "marked," and be said to necessitate a special boot, unless the difference in length between the limbs exceeds 2½ in.; but it seems to me useless, in the actual state of affairs, to attempt to modify a shortening of less than 4 in.

Marked shortening is almost always due to faulty reduction, vicious union, lateral angulation, or overriding. The most typical case is that of an externally bowed callus in a fracture of upper part of the shaft.

In these cases, correction of the deformity and lengthening of the limb by osteotomy may sometimes be considered, but for this the following conditions are necessary:

(i) The fracture must not be suppurating, the callus not osteomyelitic, there must be no sequestrum, sinus, or infected central cavity; otherwise intervention may be followed by fatal septicæmia.

(ii) The callus must not be too mis-shapen or voluminous; otherwise the operation will be practically impossible.

When these two conditions do not definitely contra-

indicate osteotomy, a marked improvement in the condition of certain cases may be obtained.

Oblique osteotomy of the callus should be performed, with a minimum of trauma ; for this purpose a Gigli saw is sometimes preferable to the osteotome. The wound should be left without sutures, and straightening effected by continuous extension in a suitable position, as for a recent fracture ; immediate straightening and reduction with metallic osteosynthesis is not advisable.

In a fracture of the upper third of the thigh, with

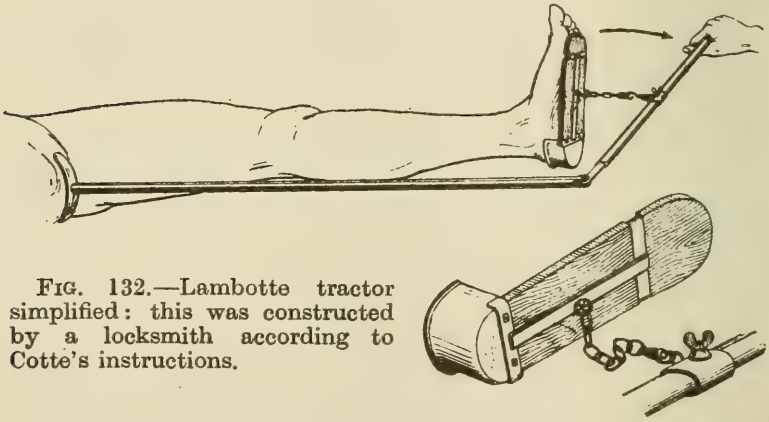


FIG. 132.—Lambotte tractor simplified: this was constructed by a locksmith according to Cotte's instructions.

marked deviation of the upper fragment in abduction, I obtained a perfect reduction in this way, with recovery of 2 inches in length.

(*f*) *A case is seen with a pseudarthrosis.*—This is a rare occurrence ; up to the present time, I have only seen pseudarthrosis of the femur in the sub-trochanteric region, and as a result of non-reduction.

Osteosynthesis by a Lambotte plate is definitely indicated in such cases.

(i) In sub-trochanteric fractures the condition of the hip-joint should first be investigated, and an attempt made to move the fragment of the femur by separating the insertions of the pelvi-trochanteric and buttock muscles with a rugine.

If the joint is immovable the shaft may simply be fixed by a plate to the sub-trochanteric border of the upper fragment, which is trimmed for this purpose. This causes marked shortening (about 2 in.), but the result appears satisfactory. I have obtained cure of a pseudarthrosis and a satisfactory recovery of function without difficulty by this operation ; the plate remains in position (observation eight months old).

(ii) In fractures of the shaft a considerable extent of the femur should be resected, until, in fact, healthy bone is reached, as in pseudarthrosis of the humerus.

Reduction is effected by a lever of the Lambotte type. I have used the simplified model illustrated above, which was improvised by a locksmith according to Cotte's instructions (fig. 132).

### III. Supra-condylar Fractures

1. Anatomical Features.—The direction of the fracture is usually oblique from behind forwards and rather irregular, with small splinters, particularly posteriorly ; its general appearance resembles that of supracondylar fractures in civil practice. At first the damage often appears not to be very great, but in reality *there are almost always several fissures radiating into the joint ;* these fissures sometimes end at the cartilage, but usually the latter is split, and the fracture of the shaft becomes an articular fracture. There is no external sign of this penetration of the epiphysis ; there is often no hemarthrosis, and the fissure is invisible in a radiograph, whatever its position, whether intercondylar or transcondylar.

Apart from these cases, a T-shaped and definitely intra-articular fracture is of common occurrence.

There is often considerable injury to the soft parts, which is increased by the rotation of the fragments ; laceration of the tissues beneath the quadriceps frequently occurs.

The point of the lower fragment sometimes comes into contact with the popliteal vessels, contusing or lacerating them.

Nerves are usually uninjured.

2. Physiological Features.—Two different forces come into play to produce the displacement, which is usually very marked: by the action of the quadriceps, the upper fragment is displaced forwards, sometimes also slightly outwards or inwards, piercing the tendon of the quadriceps, and projecting beneath the skin or into the wound.

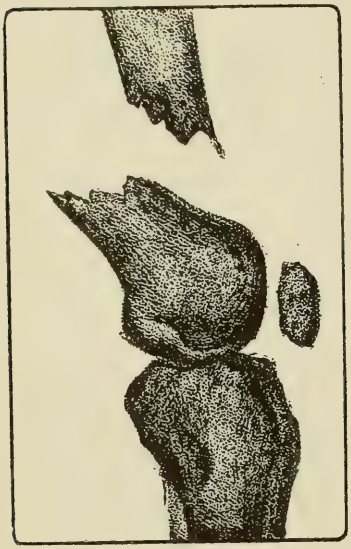


Fig. 133.—Supra-condylar fracture: the radiograph does not show a fissure which passes down between the two condyles as far as the articular cartilage.

The lower fragment is pulled backwards by the gastrocnemius and soleus, causing a pronounced rotation towards the popliteal space, and bringing the upper extremity of the epiphyseal fragment into contact with the vessels.

3. Course.—Since there is little comminution, this fracture may prove mild, provided that there are no transepiphyseal fissures, no perforation of the joint, no vascular lesion, and no subsequent sepsis. I have seen them progress without difficulty (after early disinfection), cure aseptically and without complications, but with great limitation of movements. In one of these cases a late orthopædic resection was necessary and gave an excellent result.

Usually, however, the position is less favourable; the epiphysis is split and the cartilage fissured. If the

wound is not disinfected immediately, if the fracture suppurates, infection spreads along the fissure, and after a few days of apparently favourable progress, serious suppurative arthritis suddenly develops, and immediate amputation is necessary. During the last few months I have been obliged to amputate in three cases evacuated from the front with infected supra-condylar fracture. In all three cases amputation of the thigh was necessary during the course of the third week, shortly after their transport, and in each of the three cases infection of the joint had occurred through a radiating fissured transcondylar fracture; there were very marked lesions of the cancellous tissue of the epiphysis.

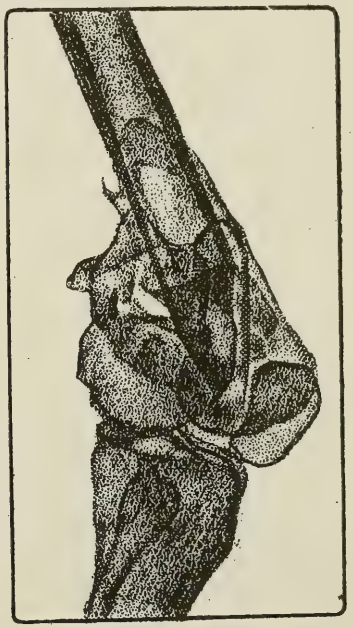


FIG. 134.—Cure with ankylosis of a supra-condylar fracture from a shell-fragment, on which no operation was performed. A small oozing sinus had persisted for a year past: ankylosis with flexion. An orthopædic resection was performed, and gave an excellent result.

Supra-condylar fracture is therefore a grave injury. When it is added that reduction of the displacement is always difficult, it will be understood why the prognosis should always be very cautious.

4. INDICATIONS FOR EARLY TREATMENT.—The frequent occurrence of fissures of the condyles which are invisible in a radiograph necessitates as careful a preventive disinfection as possible, without which arthritis is almost inevitable.

This disinfection should include sub-periosteal removal of all splinters projected into the popliteal space,

and careful and gentle curetting of the epiphyseal cancellous tissue.

If this operation is performed at an early stage, no complication of the condylar lesion occurs, even when a penetrating fissure exists. In the case of associated injury to the synovial membrane (which is common), this should be cleaned, the lacerated borders of the synovial membrane excised and the edges sutured, after which the fracture itself is treated.

If there is laceration of the vessels they are ligatured, if necessary, without abandoning conservative treatment, unless gangrene is threatening or evident.

Sometimes, however, complete exploration will lead to the discovery of lesions such that immediate amputation will appear advisable. Amputation should be performed if injury to the bone is too extensive (more than 4 inches of the femur), if the lesions of soft parts (vessels and nerves) are such as to afford little hope for the future, if, together with grave lesions, there are already signs of articular infection, and, finally, if there is gangrene of the foot.

In theory, it seems that amputation is rarely necessary; in practice it frequently is, and after these early amputations at the front, subsequent investigation of the lesions almost invariably justifies the serious decision made.

5. Technique.—In the absence of special indications furnished by the position of the wounds, the region of the fracture is approached by a lateral external incision parallel to the biceps, but slightly anterior to it, and ending below at the condylar prominence. Unless an internal incision is necessary to reach splinters that have been projected inwards, this single incision will suffice, which is an advantage from the point of view of the vessels and nerves. An incision in the popliteal space is bad, and should never be made: drainage in contact with the popliteal artery and branches of the sciatic nerve would be particularly misplaced.

As a rule, the operation is easy.

The same cannot be said of the immobilisation of these fractures. The backward rotation of the lower fragment necessitates immobilisation with the leg flexed, and the forward projection of the upper fragment necessitates flexion of the thigh on the pelvis.

Any form of immobilisation with continuous extension which does not take these two desiderata into account should therefore only be temporary.

As a provisional arrangement, at the front, the plaster trough is a solution of mediocre value, but acceptable for the time being; as soon as possible, the double inclined plane should be resorted to, which may easily be improvised with two boards of equal dimensions, united by two hinges, and fixed by a rack.

When a choice is possible, Hey-Groves's appliance (described on p. 523) should be used, and is excellent from this point of view; the suspension appliance with a jointed frame (as illustrated on p. 529, fig. 118) is good. I have treated a high supra-condylar fracture by means of this appliance, and obtained an excellent reduction. I refer the reader to details given in connection with the above-mentioned splint.

6. TREATMENT OF CASES SEEN AT A LATER STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case is seen progressing well.*—This is unusual, and up to the present I have never admitted from the front a supra-condylar fracture, due to a shell-fragment, in a good condition. Immobilisation should be effected, as has been stated above, on a double inclined plane. Continuous extension is not always necessary, but if it should be, it is carried out by exerting a strong downward pull on the condyles, in an attempt to rotate the lower fragment back into position.

Immobilisation should be continued for three or four months. Union in these epiphyseal fractures is often very slow. Considerable stiffness of the knee must be expected.

(*b*) *A case is seen in a septic condition.*—Three types of condition are possible:

(i) If it is a fracture which has not been disinfected, immediate esquillectomy is necessary. The two pointed ends are smoothed off with a Gigli saw. Any radiating fissure should be located and cleaned with a curette, the cancellous tissue in its vicinity being scraped away. If necessary, hemarthrosis of the knee is relieved by puncture.

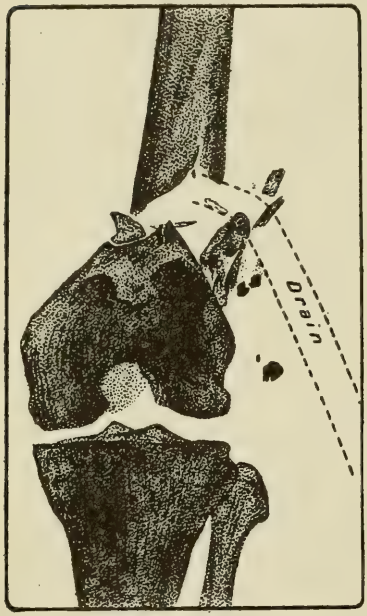



FIG. 135.—Supra-condylar fracture treated at the front by drainage of the soft parts and intermittent irrigation. Evacuation on the fifteenth day; condition apparently good. Four days later, suppurative arthritis and serious general condition; amputation of the thigh. An infected fissure, which the radiograph does not show, passed through the outer condyle as far as the cartilage, which was split.

If a penetrating fissure exists, resection of the knee should be performed at once, including removal of a thin layer from the tibia.

If the infection is not rapidly checked, the attempt at preservation should not be continued too long, but amputation should be performed without delay, even if the line of fracture and consequent shape of the upper fragment are favourable for resection of the knee; these fractures are very serious when preventive disinfection has failed.

(ii) If the fracture is seriously infected, with evident injury to the joint, which is also already infected, resection is sometimes possible, but more often immediate amputation is necessary. A few isolated

fortunate cases, which will never be anything but exceptions, cannot blind us to the fact that deaths have been caused by undue delay in amputating in these fractures.

(iii) If the foot is gangrenous, which indicates a vascular lesion, amputation is also necessary.

(*c*) *A case is seen with vicious union.*—There are vicious unions which should be recognised as unsuitable for intervention—viz. those which are still infected, or are accompanied by a large inflamed callus. On the other hand, effective intervention is possible by orthopædic resection, in simple vicious union, due to absence of reduction, with a stiffness of the joint practically amounting to ankylosis: very limited orthopædic resection of the tibia has enabled me to obtain a firm knee in the extended position. The same is the case when the shaft of the bone becomes impacted into the condyles in a position of angular deformity. In a case suffering from ankylosis with flexion of this kind, resection gave me a perfect result (fig. 134).

(*d*) *A case is seen with a pseudarthrosis.*—I have never seen an example of this, but it is a possibility, pseudarthrosis being caused by lack of reduction and muscular interposition. Operation on the region of the fracture and introduction of a Lambotte plate on the outer side seem to me the best procedures.

(*e*) *A case is seen with a sinus.*—All sinuses which I have seen co-existed with ankylosis of the knee, and curetting of the cancellous tissue after this has been widely exposed by a transverse incision easily produced a satisfactory result. The conditions may, however, be different: notably, multiple sinuses may occur, due to different causes—cancellous osteitis below, a sequestrum from the shaft above and behind. In these cases the operation should consist of several stages, each lesion being treated separately according to the nature of its cause.

## CHAPTER XVI

## FRACTURES OF THE LEG

The following groups may be distinguished:

Fractures of both bones about the middle, and in the lower third (supra-malleolar).

Fractures of the tibia alone.

Fractures of the fibula alone.

### I. Fracture of Both Bones of the Leg

In practice, fracture of the upper epiphyses of the bones of the leg is only seen as an injury to the joint, which should be treated by resection. Fractures of the malleoli are also almost always fractures into the joint. I shall only deal here with definitely diaphyseal and supra-malleolar fractures.

**A. Fractures of both Shafts.**—This term includes any fracture between the tuberosity of the tibia and the lower third of both bones, 2 in. from the malleolus.

1. Anatomical Features.—The most usual type of fracture has large diamond-shaped splinters in the tibia, and comminution of the fibula. Fracture of the tibia of the large short-splinter type, with transverse fracture of the fibula, also occurs, and still more common is comminution of both bones.

The higher up the fracture (*i.e.* the nearer to the upper tibial epiphysis) the more frequent is the comminuted type. On the other hand, the lower down the position of the fracture, the more often does the large-splintered type occur.

Lesions of the vessels and nerves are very frequent.

2. Physiological Features.—The displacement is always more marked in the tibia than in the fibula. There are two opposing muscular forces—that of the quadriceps femoris, which pulls the upper fragment forwards, and that of the calf muscles, which tries to displace the lower fragment backwards. The result is a frequent angular displacement with its apex backwards; the leg appears to form a curve with a marked anterior concavity. At the same time there is almost always lateral displacement. Lastly, the weight of the foot usually exerts a lateral pull on the lower fragment, producing a certain degree of rotation on the long axis of the bone, *i.e.* internal or external displacement by torsion. In spite of this, the displacement is never very great.

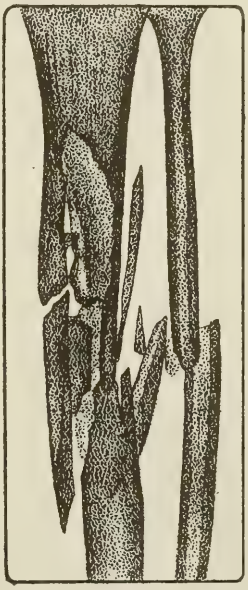


Fig. 136.—Large-splintered fracture of the tibia (common type).

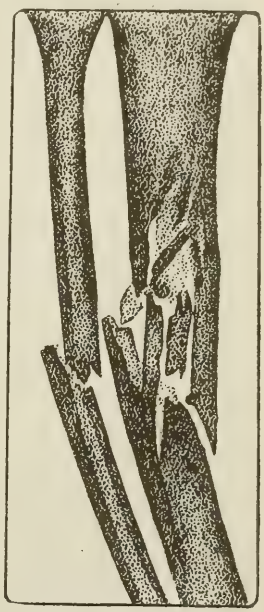


Fig. 137.—Postero-lateral angulation in a fracture of the leg.

3. Course.—When left alone, a fracture of both bones is often complicated by gas gangrene, since there is extensive muscular injury beneath resistant fasciæ, and often associated vascular lesions.

In cases which escape these immediate complications, the development of serious septic acute osteo-

myelitis of the fractured area is virtually constant and leads to the formation of sequestra, profuse suppuration, pus tracking down the calf, destruction of the fasciæ, and secondary hæmorrhage.

After drainage, which causes permanent rigid and contractile cicatrices in the muscles, one of two conditions usually develops: either a redundant inflamed callus is formed, enclosing an empty medullary cavity (see p. 306, figs. 10 and 11), or the dull white extremities of the tibial fragments undergoing necrosis are seen in the wound, and after their elimination, the devitalised ends of the shaft are left rarefied and without any sign of union, and decidedly unsuited for plating.

Of these conditions the former is the more common. Owing to the suppuration, it is difficult to ensure rigid immobilisation, and a frequent result is the formation of a faulty callus with posterior angulation, so that the leg forms a bold curve with its concavity forward, or with outward or inward displacement by torsion of the foot, and almost always a degree of pes equinus, which soon becomes difficult to correct.

In short, the cure of septic fractures of the leg is too often only very moderately satisfactory: in these, more than in fractures in any other region, anatomical preservation is by no means identical with preservation of function.

4. Indications for early Treatment.—A prophylactic clearing operation should be done as early as possible: this is a *sine quâ non* if good functional use is to be hoped for.

There are cases, however, in which this immediate operative disinfection is only a prelude to immediate amputation.

*Amputation should be performed at once* when destruction of the bone is too extensive to afford any hope of adequate anatomical repair. Judgment on this point is not an easy matter, and the decision in such a case

depends largely on the individual. In general, it is better to err in the direction of too frequent attempts to preserve the limb; sub-periosteal esquillectomy allows one to go very far in this direction without danger.

It would seem, however, that when the bone-injury involves more than half the length of the leg (not, of course, including fissures, but merely the splintered region), immediate amputation is preferable.

Similarly, when the injuries to soft parts, muscles, vessels, and nerves, are such as to afford no hope of satisfactory functional recovery, it is better to amputate at once, since preservation would cause the patient to run considerable risks for an illusory benefit.

Finally, the seriousness of the general condition may sometimes necessitate an early amputation, when an extensive area has been comminuted. But I regard this indication as extremely rare; the necessity only exists when it is of importance to demand a minimum of effort from the system (*e.g.* when the patient is almost bloodless, and in danger of grave infection). Even in such a condition as this, a more appropriate course than amputation would probably be transfusion, followed by esquillectomy later on.

In all other cases, early sub-periosteal esquillectomy should be performed at once, for the two reasons already mentioned—to prevent complications, and to facilitate union.

5. TECHNIQUE.—(*a*) *The operation.*—This is performed by means of two incisions, one along the crest of the tibia, and the other over the fibula, the existing wounds being used if convenient; there should be no hesitation in making fresh incisions at the seat of election if the entry and exit wounds are inconveniently situated.

The tibial incision should be made on the aspect of the bone internal to the crest: separation of the periosteum with the rugine is begun at once and as

much of this as possible is preserved; the region of the fracture should be carefully cleaned, and if necessary, sound bone cut away from the antero-internal surface of the tibia in order to expose its posterior aspect. Esquillectomy is then carried out in the fibula, but this need not be so extensive, as the fragments over-ride without any trouble, when the difference between the gaps in the two bones is not too great. Unless this precaution be taken, the orthopædic result is not satisfactory; mechanical forces do not act normally on the fragments, the progress of bone formation in the two bones is not correctly correlated, and there is danger of faulty union at some point, if not of pseudarthrosis. The shortening of the fibula should therefore be systematically ensured.

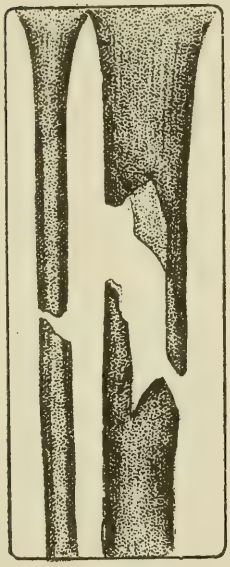


FIG. 138.—Radiograph after total sub-periosteal esquillectomy. The leg is in a continous extension plaster apparatus, of the type represented in fig. 138 (cf. figs. 136 and 137).

At the conclusion of the operation, it is absolutely useless to make an incision through the muscles of the calf, for purposes of drainage; the sole effect of this is to leave dense scar-tissue in them.

(*b*) *Immobilisation.—The essential point is that this should ensure preservation of the normal axis of the lower limb*, since any deviation from the normal static line has infinitely more serious functional results than has shortening. During the whole period of immobilisation, therefore, any angular deviation must be accurately corrected and every effort must be made to re-establish the long axis of the tibia.

During the first few days I employ a metal splint, pending the first dressing. The latter, if conditions

are normal, is postponed until the sixth or eighth day, when I finally immobilise the limb by one of the three following procedures :

*A simple posterior plaster trough* suffices in many cases, where esquillectomy has effected a complete reduction, and there is no sepsis to necessitate frequent dressing (Part I, fig. 70).

In a case of this kind, good union was observed to have occurred in thirty-seven days, when the third dressing was applied.

More often, however, *a continuous extension appliance* is necessary.

Excellent permanent traction can be applied by the use of plaster, in the following way :

Two sets of curtain-rods are prepared, one rod sliding on the other in each case ; these are cut so that, allowing for a fair amount of extension, the two rods fitted one over the other are about equal in length to the leg (fig. 139). A well-modelled plaster boot is then made, not fitting too tightly, and in the centre of the sole is incorporated a loop of bandage, or a metal hook, to act as a traction ring. The knee is next enclosed in plaster, which extends down immediately below the anterior tuberosity of the tibia. The two parts of the plaster are connected on each side by means of a pair of the telescopic shafts, which are held in position by an assistant three fingers' breadth away from each side of the leg. Each shaft is fixed firmly to the plaster at one end (fig. 139) by means of a plaster band rolled as is indicated in figs. 140 and 141. The assistant keeps the telescopic traction shafts exactly parallel to the axis of the leg until the plaster is dry, this being done first on one side and then on the other. A small splint should be incorporated in the dressing behind during the first few days to support the calf.

I have treated a considerable number of serious fractures with this improvised appliance, and the

results have been excellent. It is only necessary to be extremely careful not to immobilise the bones in a

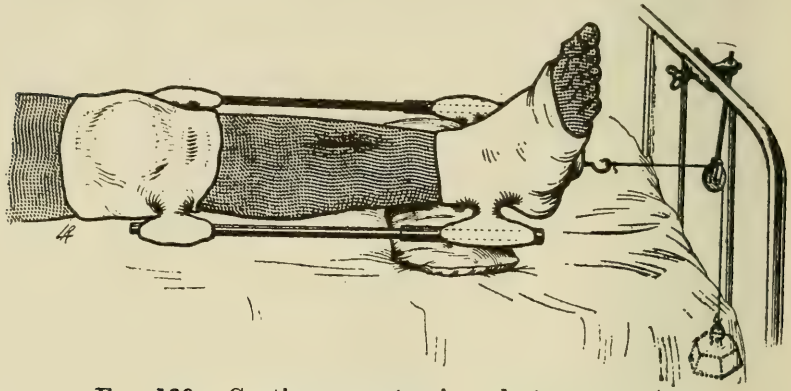


FIG. 139.—Continuous extension plaster apparatus.

bent position, and to push the upper fragment forwards before fixing the metal shafts.

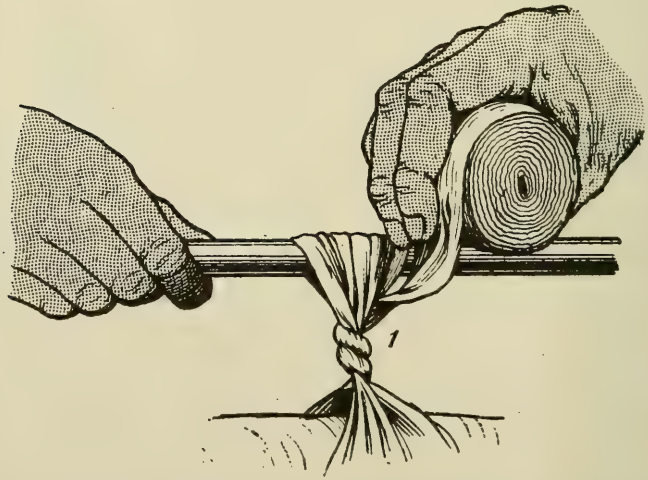


FIG. 140.—Method of fixing the sliding rods: the band passes from the plaster to the outer shaft, and is then wound in a spiral around the original loop.

Further simplification is sometimes possible, nothing being applied to the upper part of the leg but a plaster

collar identical with that in Delbet's walking appliance :

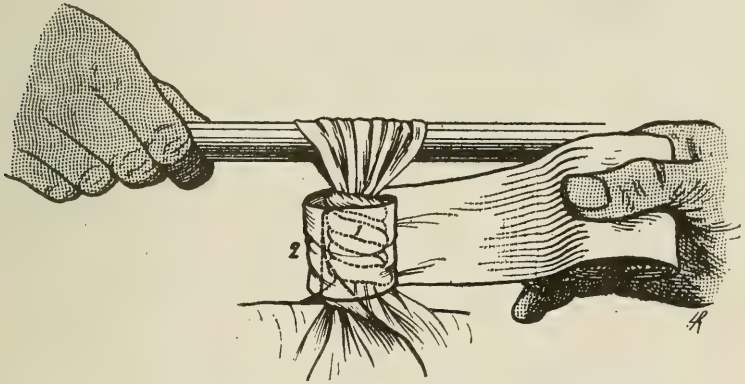



FIG. 141.—Finally, regular circular turns are made round the plaster bridge which has thus been made.

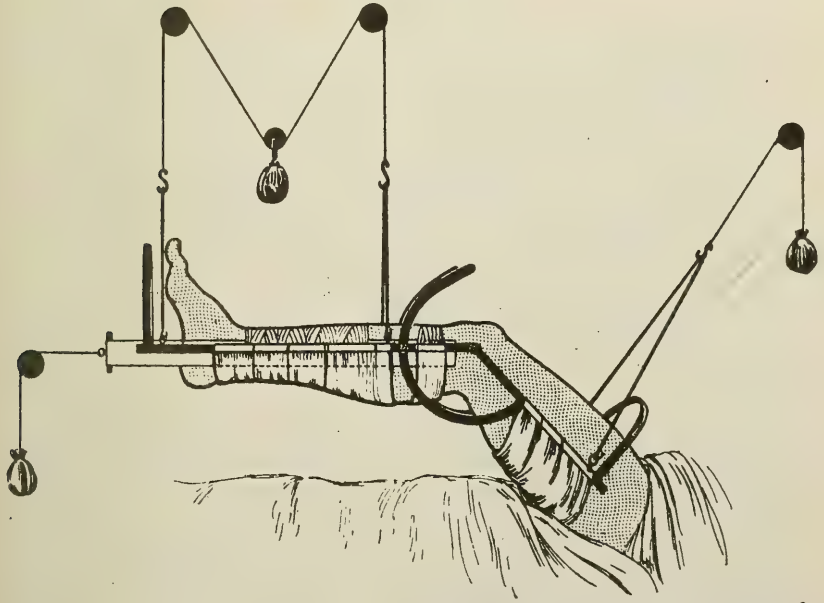


FIG. 142.—Diagram of a suspension appliance for fracture of the leg : the three suspension pulleys are attached to a horizontal bar of the ordinary type.

the knee remains free, and a certain amount of flexion is possible. As a matter of fact, it is preferable not to

employ this form of the appliance until the fracture is well on the way to unite. The telescoping curtain-rods may be replaced by a double spring shaft, comparable to those in Delbet's appliance (fig. 37, p. 376).

But in bad fractures with extensive injuries to the soft parts, these appliances cannot be used; in these cases *the suspension appliance* is the most suitable.

An appliance may be used which is identical with those described on p. 528 for fracture of the thigh, and

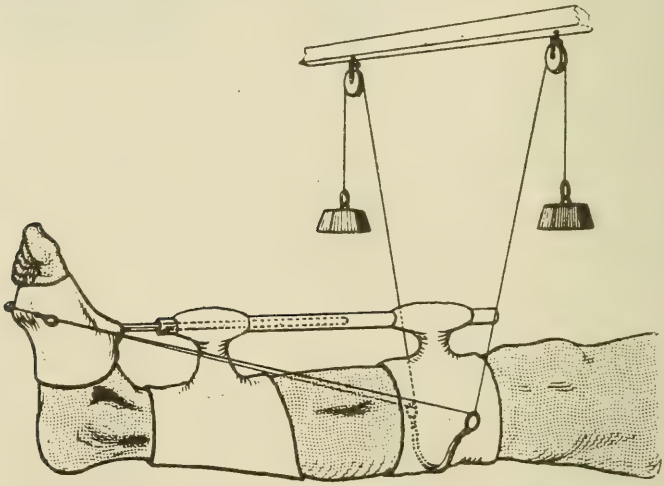


FIG. 143.—Continuous extension plaster for a fracture which is uniting, but with associated pes equinus: correction of the latter slow, owing to previous articular suppuration.

continuous traction may be exerted, the entire lower limb being in extension. It is better, however, to use a jointed frame, traction being exerted with the knee flexed. The practical details given in connection with supra-condylar fractures of the femur render further description of the appliance unnecessary. Its construction is shown in fig. 142. The counterpoise should be from 4 to 5 kilogrammes, and the extension, from a strapping stirrup, 5 to 6 kilogrammes.

(*c*) *Care of the foot.*—It is absolutely necessary to

watch the position of the foot. Bad positions of the foot too often spoil the functional result after perfect union of the fracture. Moreover, a number of these abnormal positions are due to reflex contractures which are difficult to cure. Continual attention should be given to the foot, in order to prevent the development of equinus, varus, or valgus. These details should receive consideration early in the treatment,

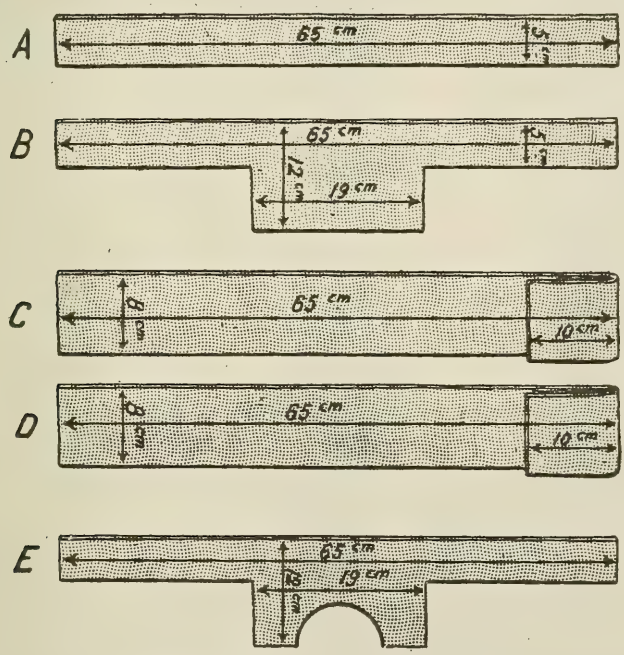



FIG. 144.—(A) Tibial piece. (B) Malleolar piece with heel-covering. (C, D) Lateral supports, 4 inches being folded back at the lower extremity. (E) Malleolar piece with heel piece.

and not towards the end. If the deformity already exists but has not developed too far, the normal position of the foot can be restored, either by means of a spring sole, or by an arrangement such as that shown in fig. 143.

(*d*) *Apparatus for convalescence.*—As soon as the size of the wounds is reduced, and union has begun,

it is an excellent practice to fit Delbet's walking appliance. This is usually permissible about forty days after the operation when there is no longer any need for continuous extension. The Scultet apparatus, which Delbet considers necessary, is not really called for : it may perhaps be more convenient, but I do not use it. To construct an appliance for walking, four tarlatan slips of the dimensions indicated in fig. 144 are prepared, and a fairly thin plaster paste, intended not to set too quickly. The slips and circular pieces are soaked in the liquid paste, spread on a table, smoothed, sprinkled with dry plaster, and placed flat on the leg. The malleolar ring is first applied, in such a way that the heel-cover does not extend below the heel. The circular tibial piece is similarly applied ; the upper border of this should coincide with, but not pass above, the anterior tuberosity of the tibia. The two lateral supports are immediately applied, care being taken not to encroach on the knee above, and to reach the border of the foot below, without passing beyond it. The upper collar is then arranged circularly around the leg and the two ends of the heel-piece are made to cross anteriorly above the instep, which should remain free. Nothing now remains but to mould the whole to the limb with an ordinary bandage, being careful to keep the foot exactly at a right angle, while moulding the heel-covering on the malleoli.

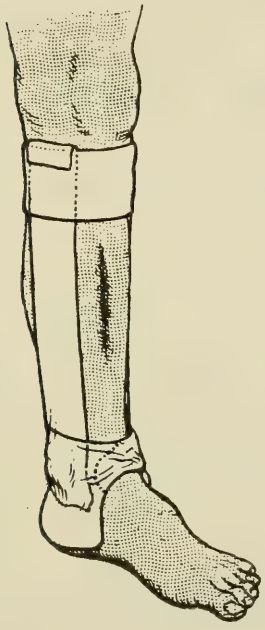


FIG. 145. — Delbet's walking appliance for fracture of the leg.

6. The Treatment of cases seen at a later stage or after previous Treatment.—(*a*) *A case is seen doing well after several days.*—The wounds are insignificant, and the fracture is apparently going

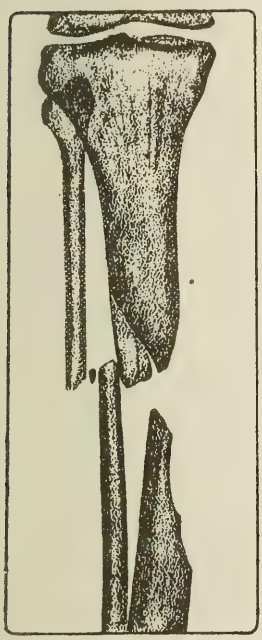


Fig. 146

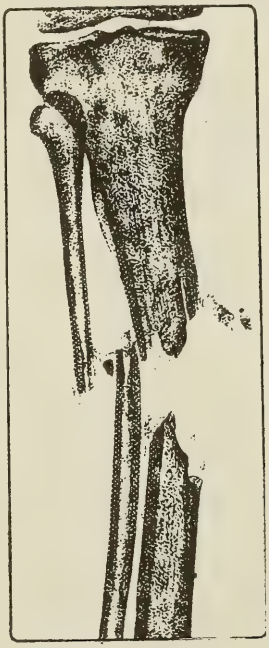


Fig. 147.

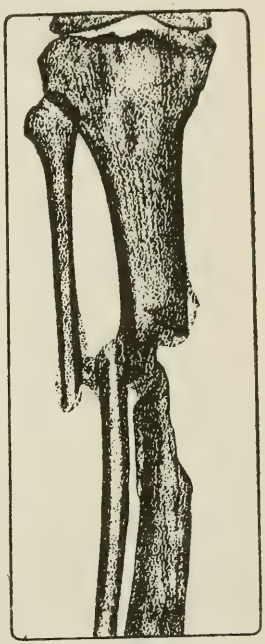


Fig. 148.

Fig. 146.—Severe fracture of both bones of the leg caused by a shell-fragment; sub-periosteal esquillectomy on the fourth day, followed by removal on the eleventh of a splinter that had been overlooked; radiograph on the fourteenth day.

Fig. 147.—Radiograph two months later.

Fig. 148.—Radiograph at the end of eight months. Union took four months, and was effected in a continuous extension plaster of the type represented in fig. 139. In spite of the tibio-fibular synostosis, the longitudinal axis of the bone is preserved; the result, from the point of view of function and equilibrium, is good. Musculature good. No sinus. Shortening of half an inch.

on as if it were caused by a bullet with punctiform wounds. It is necessary and sufficient to apply continuous extension for three or four weeks, and then to fit a walking appliance.

(*b*) *A case is found to be infected.*—The wound dates from some days previously, the leg is swollen, and there is suppuration. Complete sub-periosteal esquillectomy of both bones should be performed at once, care being taken to reduce the fibula to the same length as the tibia. Abscesses should be opened, but, except when definitely necessary, no posterior counter-incision for drainage is made, as this is useless. Immobilisation in plaster, with continuous extension, or in suspension, is immediately effected.

Under these conditions, if the case is carefully dressed and the position of the fragments continually re-examined, marvellous results will be obtained : very grave fractures will be cured without leaving any effects, and function will be recovered practically entirely (figs. 135, 136, 137, 145).

The position of the foot must be watched carefully in these cases : it will sometimes be necessary to contend with pes equinus ; in a complex case, in which I was obliged to perform arthrotomy of the ankle during treatment of a serious fracture, I used the arrangement indicated in fig. 139 to counteract pes equinus and to restore the foot to its normal position.

(*c*) *A case is seen at a late stage, seriously infected.*—The first month has passed, the periosteum has already reacted, and the outlines of a callus have been formed, but the wound is suppurating profusely, and sequestra are beginning to be eliminated. At this stage, esquillectomy is no longer possible ; the treatment will be merely drainage of the soft parts and removal of sequestra that require to come away. Intervention, if it is not to be dangerous, must be delayed until the osteomyelitis has been reduced to some extent.

If the lesions are very extensive, if the general condition becomes worse, if the temperature remains high after adequate drainage, and particularly if the shortening, due to elimination of sequestra, is marked (3 to

4 in.), and there are serious associated muscular and nervous lesions, it will sometimes be necessary to decide on amputation. Late secondary amputation has two indications which are very real, but difficult to express : it should be considered (1) when the general condition does not justify waiting too long for slow and probably poor anatomical repair, and (2) when the local conditions afford no hope of sufficient functional recovery.

(*d*) *A case is seen with a fistulous callus.*—In general the tibia is concerned, and there is either an osteomyelitic central cavity, with or without sequestra, or the bone is thickened by a condensing osteitis, which keeps up persistent ulceration of the skin.

In the former case, after careful separation of the periosteum, the wall of the cavity must be cut away and smoothed, exposing the medullary canal, in order that the cavity may be disinfected by exposure to the air, and ultimately filled in.

In the latter case, the hypertrophic bone must be gouged away, and the bone cut down, until the medullary canal, or what remains of it, is encountered, not by hollowing out a narrow groove, but by chiselling away the bone over a large area : there is no danger of carrying this too far.

Sinuses and osteitic ulceration may always be cured successfully in this way.

(*e*) *A case is seen with a pseudarthrosis.*—Usually pseudarthrosis only occurs in the tibia ; it is a more or less compact fibrous pseudarthrosis with bony union in the fibula. It is most common in the upper third of the bone at the junction of the epiphysis and shaft. Lower down, if union fails, it generally does so in both bones.

Before undertaking any treatment, the region must be disinfected if any sign of infection remains, sinuses must be cleaned, and sequestra removed ; then the area is widely exposed, without waiting for cutaneous

healing, the fibrous tissue between the two fragments is excised, and the extremities of the shaft are resected on each side until apparently healthy tissue is encountered. When two healthy surfaces of bone have been thus obtained, sufficient of the fibula is resected sub-periosteally to permit apposition, and the tibia

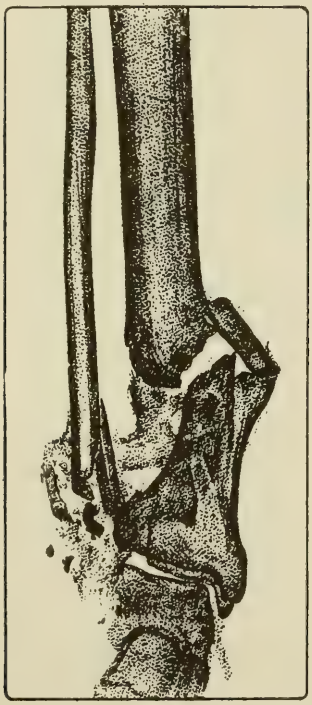


FIG. 149.—Vicious callus with multiple sinuses a year old.

FIG. 150.—Forcible reduction with osteosynthesis : uneventful recovery.

is fixed by one or two Lambotte plates. The wounds are left open, without sutures, and rigorous immobilisation is effected with plaster.

By this method I have brought about union without difficulty in the few cases of pseudarthrosis of the leg on which I have operated.

Bone-grafting is not advisable at this stage : or-

ganisms are latent in the tissues and no reliance can be placed on the result. I have never performed the operation, but at medical boards I have seen numerous failures, of which one hears nothing.

Lastly, there are pseudarthroses which require amputation. It must be remembered that the leg exists to carry the weight of the body in walking. If the pseudarthrosis is incurable, or if operation could only end in so much shortening that function would be irremediably lost, amputation is preferable, and it is useless to defer it.

*(f) A case is seen with a vicious callus.*—If the callus permanently interferes with walking, both bones must be re-fractured, and the misshapen callus must be cut away with chisel and mallet until the newly formed bone has been removed and reduction has become possible. When this has been done, tibial osteosynthesis is effected with a metal plate; the wounds are left open, without suture, and the leg is carefully immobilised in a posterior plaster splint: a very satisfactory result will generally be obtained (figs. 149 and 150).

**B. Supra-malleolar Fractures.** — 1. ANATOMICAL FEATURES.—According to my experience, there is usually one main line of fracture in the tibia, separating the epiphyseal end from the shaft. This is flanked either behind or in the space between the tibia and fibula by two or three scale-like fragments which may extend down into the ankle-joint. The line of fracture may be definitely transverse; more often, it is oblique antero-posteriorly and from above downwards. In these cases the lower fragment has a very sharp upper point, about 3 inches in length. It might be described as an incomplete spiral fracture. There is a comminuted fracture of the fibula without displacement of the small longitudinal splinters.

2. PHYSIOLOGICAL FEATURES.—In transverse fractures the foot is pulled backwards and upwards by

the gastrocnemius, soleus, and plantaris, and the shaft fragment projects forwards.

In oblique fractures the foot rotates backwards in the same way, and the lower fragment, the point of which forms a projection anteriorly, faces upwards and backwards, while the upper fragment is carried downwards and backwards by the action of the flexors of the foot. Lateral deviation almost always exists, but not in any constant direction.

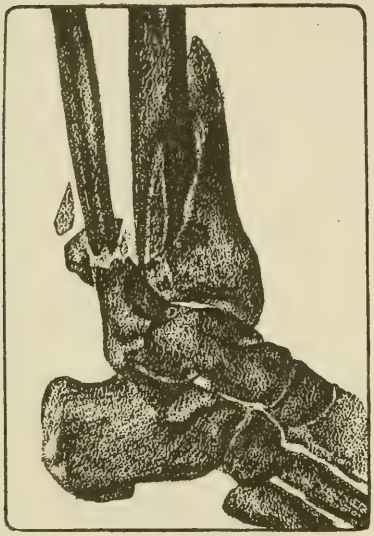


FIG. 151.—Fracture of the lower end of the bones of the leg, with large oblique anterior tibial fragment, and small posterior fragment.

3. COURSE. — The gravity of these fractures is due to the possibility of secondary infection of the joint through radiating fissures, and also to the difficulty of reduction.

If the lesion becomes septic, arthritis of the ankle-joint is possible, and sometimes leads to amputation of the leg. Pus may also track along the tendon sheaths, and sometimes forms a prominence in the sole of the foot.

In the most simple cases a large deformed callus forms, and the position is bad.

In my opinion, these fractures, orthopædically speaking, and from the point of view of functional restoration, are, with the exception of those of both bones of the forearm, the most difficult fractures to treat.

Little control of the lower fragment is possible, and unless it is inadequately restored to its proper position, a curvature (concave posteriorly or anteriorly) with a considerable degree of pes equinus results. The latter

does not always affect function seriously, and may even sometimes be useful as in some degree compensating for the deformity from the static point of view, but good reduction is much preferable. There is almost always some degree of varus or valgus also.

Finally, when union has occurred, there is usually

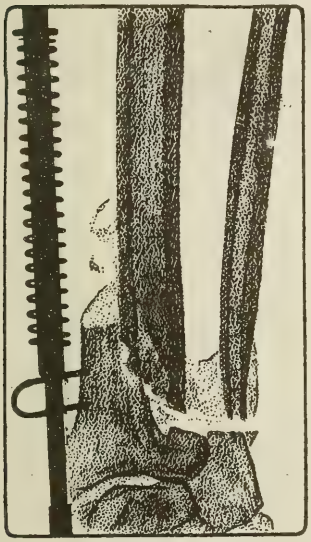


FIG. 152.—Same case as fig. 151. After esquillectomy, and fitting a continuous extension apparatus (plaster with Delbet's rods), traction is still inadequate, and the fracture is not reduced.

FIG. 153.—Final result after three months of continuous extension. From the front the reduction seems perfect. Viewed laterally, slight rotation forward is still evident.

appreciable shortening and deformity, necessitating the wearing of an orthopædic boot.

4. INDICATIONS FOR EARLY TREATMENT. — The wound must be disinfected and the fracture reduced.

(*a*) *Disinfection* should be effected as soon as possible by esquillectomy. In these fractures, however, the splinters are not numerous. In transverse fractures two incisions are made, one on the internal aspect of the tibia, and the other over the fibula, and the lateral

fragments are removed. The fibula is shortened as may be necessary by sawing off enough of the supra-articular cancellous tissue to reduce it to corresponding dimensions with the tibia. When the fracture has been cleared in this way, its posterior aspect is examined ; it is not unusual to find small spicules of bone here which must be removed with great care. In

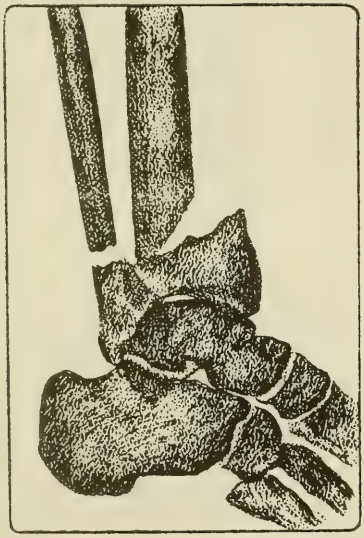


FIG. 154. — Infected supra-malleolar fracture. Radiograph after total sub-periosteal esquillectomy on the fourth day.

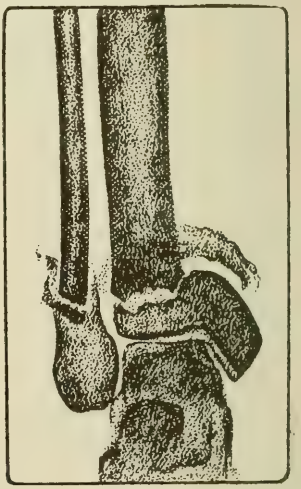


FIG. 155.—Result given by continuous extension after three months. Fracture united by a very translucent but resistant callus.

oblique fractures, part of the tapering extremity of the lower fragment must be removed, in order to expose the region well, and to explore it thoroughly. This has not appeared to me to facilitate its reduction.

(*b*) *Reduction* is very difficult, as no direct hold on the lower fragment is possible.

At first, post-operative manual reduction during anæsthesia is sufficient, with immediate application of plaster. But as soon as possible something better must be done : continuous extension is necessary,

but is inadequate if applied in the usual way. I have often exerted the pull through stirrups incorporated in the dressing, without ever succeeding in obtaining perfect correction. A better result is given by suspension, because less force is lost, and the traction is better utilised. Even this, however, is not ideal. Without experience of it, I am inclined to believe that extension by nail transfixion or the Finochietto stirrup is definitely indicated. The danger of infection will be urged against this, but it is not great, and the danger of non-reduction is certainly more urgent.

5. THE TREATMENT OF CASES SEEN AT A LATE STAGE OR AFTER PREVIOUS TREATMENT.—(*a*) *A case has done well without operation.*—In these cases, treatment should be directed solely to reduction and immobilisation. For this purpose I believe the best apparatus to be a suspension appliance, with traction by means of the Finochietto stirrup (figs. 33–35).

(*b*) *A case arrives with sepsis in the secondary period.*—Immediate esquillectomy, as described above, is necessary ; it should be comprehensive, every effort being made to overlook nothing. Immobilisation should be based on the same principles.

When the injury to soft parts, tendons, muscles, and skin is too extensive, amputation may be justified, not because it is impossible to check the infection, but because a deplorable functional result is to be anticipated. Judgment is only possible in individual cases, and it is impossible to give a definite rule on the subject.

(*c*) *A case arrives with a sinus.*—Sometimes this is a simple matter, and the removal of a sequestrum is sufficient to effect cure. But much more often extensive clearance of the tibia is necessary, and even actual sub-periosteal resections of the shaft, in order to bring about recovery.

(*d*) *A case is seen with equinus.*—Some cases of this sort are compensating, and no interference should be attempted ; value should be attached in these cases

rather to functional usefulness than to anatomical appearance.

Sometimes, when there is vicious or painful ankylosis, astragalectomy is indicated. On the other hand, this has little effect on a vicious callus, and under such circumstances direct operation on the region of the fracture is preferable. On several occasions I have performed double osteotomy in the fractured region, followed by osteosynthesis, with excellent orthopædic and functional results. This is the ideal treatment for a vicious callus.

## II. Fracture of the Tibia

There are three types of fracture of the tibia alone :

Fracture of the upper end.
Fracture of the shaft.
Fracture of the lower end.

**A. Extra-articular Fracture of the Upper End.**—This is a fracture of a very special type. The superficial wound is small, but the cancellous tissue is extensively crushed by the projectile, close up to the articular cartilage. In a few days this contused cancellous tissue undergoes necrosis, and a foul form of sepsis develops which affects the joint ; in many cases amputation in the thigh becomes necessary.

When the infection is less violent, a chronic suppuration develops, with slow necrosis and gradual elimination of the cancellous tissue, which frequently ends in ankylosis of the knee and sinus-formation, or in pseudarthrosis.

Sometimes union occurs, but it is then almost invariably vicious, the lower fragment sliding backwards upon the upper and producing the deformity known as a " bayonet leg."

In short, therefore, this is a serious fracture. It should be treated by early, if not immediate, removal

of all contused cancellous tissue. For this purpose, the region must be widely exposed, if necessary by making a crucial incision, and freeing with a rugine the periosteum into which the patella tendon is inserted; the anterior wall of the fracture area is removed, and the cancellous tissue carefully cleaned with the curette until apparently healthy bone is encountered.

After this, the limb is immobilised in a plaster case which presses the lower fragment forwards. This arrangement is temporary only, and should be replaced later by a suspension immobilisation appliance (see fig. 140). Backward rotation of the lower fragment is thereby prevented by excluding muscular action.

The same treatment should be adopted as a *secondary measure*. The wound should then be left widely open, and any small fragments of bone remaining, which are usually eliminated by degrees, should be looked for; if necessary, occasional applications of the curette are made. The wound should then progress aseptically, but the healing, and the filling-up of the large cavity excavated in the cancellous tissue, must be closely attended to. Sometimes the latter may be plugged, and left exposed to the air and, particularly, to the sun. Recovery takes three to four months.

*A sinus* is treated by opening up widely; in certain cases a large cavity will be found in the epiphysis, and resection of the head of the bone will be necessary. The cartilaginous surface of the femoral condyles is removed, and the surfaces of the femur and tibia are nailed together as after a typical resection. It will be necessary to cut a groove in the external condyle, for the head of the fibula.

*Pseudarthrosis* necessitates a freshening of the bone ends in the case of the tibia, and removal for adaptive purposes in the fibula. Fixation of the fragments of the tibia is necessary; I have twice performed it successfully at the fistulous stage.

**B. Fractures of the Shaft.**—There are many lateral

wounds of the tibia, with fissures radiating beneath the periosteum, but with no true fracture. Complete fractures without injury to the fibula are uncommon. The fracture is hence almost always one with large diamond-shaped splinters, more or less disposed in the classical "butterfly-wing" manner, or as a spiral fracture. There is usually very little displacement, the fibula being intact.

The course of these fractures is identical with that of fractures of the leg, in which the tibial element is much the more important: grave infection, acute osteomyelitis, diffuse cellulitis of the calf, and later, chronic osteomyelitis, suppuration, and sinus-formation. Owing to the elimination of sequestra, it is not unusual to see union fail to occur, the fibula acting as a rigid support, and keeping the fragments of the tibia apart.

The first step is free esquillectomy, the periosteum being preserved. Subsequent treatment is conducted as already described. Immobilisation is effected by a simple plaster trough. Any extension appliance is useless, because the fibula is intact.

If esquillectomy has left an appreciable interfragmentary gap, and if this still appears considerable in a radiograph after three or four weeks, an adaptive resection of a sufficient length of the fibula ($\frac{1}{2}$ to 1 inch) is carried out as a precaution to prevent pseudarthrosis.

**C. Fracture of the Lower End.**—Isolated fractures of the internal malleolus are sometimes seen, with fissures, and often detachment of splinters, both involving the joint. If the fracture continues aseptic, the articular lesion is unimportant. If the infection is superficial, slight arthritis develops, which almost always ends in ankylosis of the ankle-joint. Sometimes the infection is deeper, and suppurative arthritis develops; this is exceedingly rare, and the cases which are being discussed here should be clearly distinguished

from definitely articular wounds, complicated by a malleolar fracture, which are discussed in Part I, p. 242.

In isolated fractures of the tibial malleolus, limited esquillectomy is usually sufficient: the early removal of the small splinters and the fragment which extends into the joint, ensures an uneventful development of the fracture. Cure is complete in about forty days.

On the whole, this fracture is not a severe one.

### III. Fracture of the Fibula

Three types may be distinguished in practice:

Fracture of the head and neck.
Fracture of the shaft.
Fracture of the malleolus.

**A. Fractures of the Head and Neck.**—These are generally fractures by crushing of the cancellous tissue, with one or two small compact splinters at the point of junction with the shaft.

There is no displacement, in spite of the presence of the biceps tendon, but the external popliteal nerve is frequently involved.

Being very superficial, the fracture is not complicated by serious septic conditions, and the vicinity of the knee-joint is of no practical importance. But as cancellous tissue is concerned, it is usual for osteitis to continue indefinitely, delaying a final cure, while the infection, giving rise to the formation of scar tissue, reacts seriously on, and sometimes causes secondary paralysis of, the neighbouring external popliteal nerve. Cure often occurs after elimination of a considerable part of the bone, but the loss of bone-substance caused in this way has no effect on equilibrium. Prolonged suppuration, however, lays up the patient for a considerable period.

It would therefore appear advisable, as soon as the case has been examined, to perform total sub-periosteal

esquillectomy. This operation need only be a resection in exceptional cases: resection, in fact, would inevitably open the upper tibio-fibular joint, and this, in about 12 per cent. of cases, communicates with the synovial cavity of the knee-joint. A risk would therefore be run, which it is better to avoid. Esquillectomy is performed by means of an incision which at once exposes the external popliteal nerve, in order to safeguard it from injury. The incision should be made, not directly over the bone, but posterior to it, along the biceps tendon, which forms an obvious prominence beneath the skin. The incision is begun about an inch above the head, and directed along the bone in such a way as to correspond with the interstice between the soleus and the peronei muscles. When protection of the nerve has been ensured, esquillectomy is carried out as usual, with a rugine.

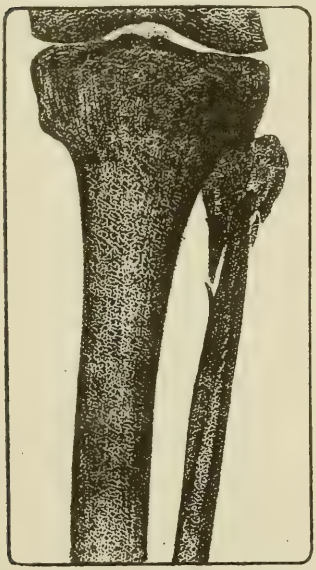


FIG. 156.—Fracture of the fibula, with osteitis of the whole head of the bone, and secondary paresis of the external popliteal nerve. Complete secondary resection of the head of the bone was necessary.

The operation over, immobilisation for a few days is advisable, without plaster or splint.

The subsequent course is usually uneventful; treated in this way, these fractures are almost featureless.

**B. Fractures of the Shaft.**—Either the fracture is comminuted, or it has short fragments and radiating fissures. Owing to the laceration of neighbouring muscles, this very simple fracture should be treated as rigorously as any other, in order to avoid the tracking

of pus, cellulitis of the calf, secondary hæmorrhages, etc., which develop when any wound or fracture, whatever its initial appearance, is not systematically cleaned. Esquillectomy should therefore be performed at once, the bone being exposed by an external incision over its prominence, and all the splinters removed after being separated from the periosteum. A careful search is made for the smallest fragments of bone, which are often driven into the calf muscles: I have several times found them between the peroneal and posterior tibial vessels. This avoids subsequent vascular complications, which otherwise occur frequently, and the simplicity and rapidity of healing will cause surprise. I have seen the periosteum form a column of new bone uniting the two fragments. I have also seen regeneration fail to occur, but this is of no practical importance.

At a later stage the same methods should be applied: phlegmon of the calf, which is the usual evidence of infection of the fractured region, is very rapidly checked by these means. Unless speedy action be taken, there is prolonged suppuration, followed by lardaceous sclerosis of the calf-muscles—with secondary equinus—necessitating orthopædic corrections at a late stage which are often difficult. In pes equinus due to muscular contracture, lengthening of the tendo Achillis by a Z-shaped incision gives little result: it is better to shorten the skeleton, and adapt it to the muscular retraction by performing astragalectomy. Quite recently I have performed temporary astragalectomy for cases of this kind, sawing through the bone horizontally, and immediately replacing the upper half of it: the results have been perfect; the movements of the ankle-joint have been entirely recovered, and the length of the limb has only been reduced by half an inch.

**C. Fracture of the Malleolus.**—These fractures are usually not serious. This is fortunate, since preserva-

tion of the external malleolus is essential for the satisfactory equilibrium of the foot. These fractures should be clearly distinguished from intra-articular fractures of the astragalus complicated by injury to the external malleolus.

The limited esquillectomy which is necessary is usually sufficient to ensure an uneventful course.

If there is slight articular infection, simple immobilisation may be sufficient; but there should be no hesitation in doing astragalectomy in the event of an acute septic condition.

## CHAPTER XVII

## MULTIPLE FRACTURES OF THE LOWER LIMB

THESE are not uncommon: they call for rigorous application of the principles laid down for each variety of fracture considered separately—that is to say, immediate sub-periosteal esquillectomy, primary or secondary, according to when the case is seen. The necessity for esquillectomy is more pressing in these complex cases than in any others.

The only really difficult problem presented by these fractures is that of immobilisation. Temporarily, and as an appliance for transport, plaster is the best medium; but as soon as possible, recourse should be had to a suspension appliance, either extending the entire lower limb, or, better, arranging the thigh in flexion on the pelvis, and the leg in flexion on the thigh. It is easy in the latter case to apply a double extension, one to the thigh and the other to the leg (see fig. 142).

*Double fractures of a bone* should be treated on similar lines, and a useful limb can be preserved by esquillectomy even in the most complex cases. I have personally treated and cured a double fracture of the femur by double sub-periosteal esquillectomy, and a bipolar fracture of the bones of the leg by resection of the knee above and esquillectomy below. The case was cured with a shortening of $2\frac{1}{2}$ inches.

# SECTION II

# FRACTURES OF THE LOWER JAW

# FRACTURE OF THE LOWER JAW

## CHAPTER I

### INTRODUCTION

THE study and therapeutics of fracture of the mandible are not, in their inception, the outcome of the war. It cannot be denied, however, that our knowledge of the subject has been greatly advanced and consolidated by the vast amount of clinical material which has come under observation since the outbreak of war. The writings and research-work of Claude Martin had previously provided a source of knowledge of the most fundamental kind, but the literature of the subject, with this exception, was mainly bibliographic in character, no surgeon or stomatologist at that time possessing personal experience of any great value. Claude Martin alone, by his patient investigations and his undeniable genius, was able to evolve the basic principles of this branch of surgical science.

But even he was able to bring together only a comparatively limited number of facts. His observations were largely founded upon the operative results of

resection of the mandible, valuable clinical material being contributed by Ollier. His knowledge of fractures was, however, unfortunately confined to the few cases which in normal peace-time come under observation. Not only are such cases comparatively rare, but they are observed under the most favourable conditions, loss of substance being an infrequent complication. Claude Martin's investigations are already ancient history, and since his day the methods of clinical procedure, especially in the domain of surgery, have become transformed, and it is obvious that the results to which they lead must also be very much modified.

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One of the most unexpected revelations of the surgery of the war is the small number of fatal results in wounds of the face. If we exclude those cases in which there is severe hæmorrhage or in which the general condition is bad, cases which never reach a base hospital, the mortality is extraordinarily low. The present generation of surgeons has been brought up in the wholesome dread in these cases of septic complications, such as pyæmia of buccal origin, and septic broncho-pneumonia, conditions whose occurrence one would naturally expect in cases where there is great difficulty in feeding the patient. Statistics derived from every centre of treatment, however, show entirely favourable results. The mortality barely reaches 1 per 1,000, and is frequently lower. Monthly reports from the surgeons in charge of these centres

show that their work is practically confined to the restoration of function, life in any case being assured.

It is not surprising that, under the present conditions, technical research has attained a development and yielded results which were undreamt of before the outbreak of war. In those past days a fractured mandible was a serious matter. Few civilian surgeons had any practical experience of the various appliances

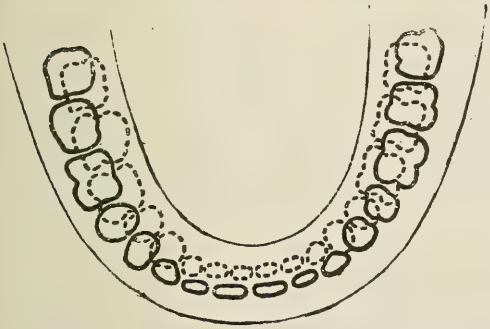

FIG. 1.—Normal dental adjustment seen in the horizontal plane. The inferior arch articulates within the superior arch, the inferior median teeth being behind the superior median teeth, and the inferior lateral teeth inside the corresponding teeth of the upper jaw. (The inferior teeth are indicated by means of dotted lines.)

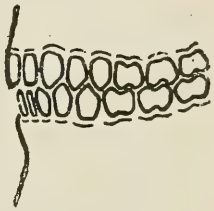

FIG. 2. — Normal dental adjustment viewed in the vertical plane. The posterior two-thirds of the inferior molars corresponds to the anterior two-thirds of the corresponding teeth of the upper jaw.

recommended by the text-books, appliances, moreover, which were largely unobtainable. In later years, however, dentists were appointed to the hospitals in most of the larger towns, and where these worked in collaboration with the surgeons better results were obtained,

[1] Emphasis is laid upon the fact that these favourable results depend upon the exclusion of hopeless cases, such as do not leave the first dressing stations.

though even here the paucity of clinical material stood in the way of both surgeon and dentist.

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Before entering upon a detailed description of fractures of the mandible it is advisable to enumerate certain physiological peculiarities of this bone, which differs considerably from those upon which surgeons are usually required to operate. The minuter details of the movements of mastication need not detain us here ; it will suffice to describe them on broad, general lines.

Mastication can only be performed when the upper and lower teeth are in normal occlusion with one another. Their position in regard to one another is shown by figs. 1 and 2, which illustrate respectively the horizontal and vertical planes. Fig. 1 shows that the position of the mandibular dental arch is within that of the maxilla, the mandibular median teeth being behind the maxillary median teeth and the mandibular lateral teeth within the corresponding teeth of the maxilla. Fig. 2 shows that the maxillary teeth are slightly superimposed, in such a way that the mandibular first molar articulates with the anterior portion only of the corresponding tooth of the maxilla, one-third of its surface being in contact with the maxillary second premolar. The combination of these relationships constitutes what is known to dentists as the "dental articulation" (occlusion of the teeth). To avoid confusion in terminology, however, we propose throughout this book to employ the term "dental adjustment."

Efficient mastication is dependent upon normal dental adjustment, and the ideal method is to preserve it. Rigidity of the mandible is, however, of equal importance, for it is evident that, once this rigidity is lost, the power of the mandible is reduced by half, for each fragment is subject to the action of one only of two sets of muscles. A condition of instability is thus established which still further impedes the masticatory function.

Dental adjustment and mandibular rigidity are the fundamental conditions aimed at in the treatment of fractures of the lower jaw. Fracture by projectiles is, however, almost invariably accompanied by loss of substance, and the surgeon finds that he is faced with a choice between two evils. To preserve the adjustment the fragments must remain apart, with consequent pseudo-arthrosis. To obtain rigidity the fragments must be brought together, with consequent disturbance of adjustment. In certain cases, as will be shown later, it is possible to avoid both evils, but in the majority of instances the surgeon is compelled to make a choice.

Claude Martin was inflexibly in favour of the preservation of dental adjustment, and it seems certain that in no case was he willing to sacrifice it in order to obtain rigidity of the bone. His views were undoubtedly influenced by the nature of the cases which passed through his hands. In his experience loss of substance was mainly the result of surgical intervention, and, the tissue removed being almost in-

variably morbid, economy in its removal would have been misplaced. Under these circumstances there would have been little wisdom in seeking to effect a union which, had it been practicable, must have been imperfect. This is no doubt the explanation of Claude Martin's adherence to the maintenance of adjustment. His method was, by means of an apparatus, to preserve the spacing of the teeth as it existed before operation. Not only did he not obtain rigidity, but the presence of the apparatus itself largely militated against it.

Experience in a large number of cases of maxillo-facial mutilation has led us to abandon Claude Martin's principle in its entirety and to sacrifice dental adjustment to bony rigidity. That pseudo-arthrosis constitutes a grave functional defect cannot be denied; that it is not susceptible to correction by means of an apparatus will be shown later. Our cases differ, of course, very considerably from those of Claude Martin; we have to deal with extensive loss of substance, and pseudo-arthrosis is frequently inevitable. Experiments in bone-grafting have been attempted, and this method may, at a later date, yield favourable results. There is, however, a large class of patients, perhaps the largest, in whom the loss of substance does not exceed two or three centimetres. In all these cases rigidity is obtainable either by means of an apparatus or by surgical means. In either event the fragments must be brought together, with consequent disturbance of adjustment. In our opinion the diminution of function is more than compensated by the benefit

which these patients derive from the rigidity of their lower jaw.

Where the loss of substance is small, the disturbance of adjustment is practically inappreciable ; up to one centimetre it appears to be negligible. Where there is a gap of two or three centimetres the case is different, but even here the error in adjustment is largely reducible. It is possible to confine the error to one fragment only, and that the smaller ; to arrange in fact, in a manner which will be described later, that it shall bear the entire brunt of the displacement. The larger portion, that which contains the greater number of teeth, remains in perfectly normal accord with the maxilla. Thus the disturbance of adjustment affects only a small portion of the jaw, and, owing to the vicinity of the site of fracture, it is usually in this portion that the greater number of teeth are missing. Indeed, it frequently happens that the posterior fragment does not contain a single tooth, and the disturbance of adjustment thus becomes purely theoretical, all the teeth present being in perfect occlusion.

To appreciate the advantage of this method, it is only necessary to compare the condition of a patient whose mandible is rigid with that of one suffering under the disabilities of pseudo-arthrosis. The former requires merely an apparatus containing a few artificial teeth, and, more often than not, he is content to masticate upon the sound side of his jaw. His condition is practically normal, and it is not necessary to give him his discharge. The second class of patient

is in a very different position. He is furnished with a corrective mechanism which is indispensable to his existence. Even with this aid his mastication is so imperfect that it is necessary to discharge him with a grant, or even with a pension.

It has seemed to us imperative that this question of method should be clearly stated from the outset. We feel that the case for mandibular rigidity in preference to dental adjustment has been proven, and that, as we shall show later, in the vast majority of cases, it constitutes the only sound therapy.

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The movements of the mandible are effected by means of the two temporo-mandibular joints. These are extremely complex, and, in addition to movements of elevation and depression, they effect also movements of projection and retraction. They possess a specific solidarity, each joint being incapable of action without the other. In the same way that torsion of the forearm is possible only when the interlines of both elbow and wrist are intact, so depressor movements of the mandible are suppressed by ankylosis of one or other of the mandibular joints, immobilisation of the entire bone resulting from a unilateral lesion. Cases of this sort, though rare, are not unknown.

On the other hand, the duplicate articulation of the mandible carries with it certain very decided advantages. These joints are so strong that the clenching capacity of the teeth amounts literally to a feat of strength. Their configuration, moreover, permits of

certain displacements which may become permanent without in any essential particular affecting their solidity. Dentists are able, with comparative ease, to manipulate the jaw in such a way that the whole of the lower row of teeth is brought slightly forward, and this position can be rendered permanent. This manœuvre, which is known as "jumping the bite," is obviously dependant upon the play of the two articulations.

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The number and variety of the movements which it is able to effect lend to the mandible a peculiar physiological interest. It possesses yet another quality which, to the surgeon, is of even greater value, namely, its capacity for immobilisation. This is greater than that of any other bone in the body. By attaching an arch with studs to each row of teeth and firmly ligaturing the two arches together with brass wire, the jaw becomes absolutely immobilised. It is this capacity for complete immobilisation which renders possible the rapid consolidation of fractures; even those in which the loss of substance is comparatively extensive. More important still, the apparatus for immobilisation, though it debars mastication, does not prevent feeding. Liquids can readily pass through the dental interstices, the retromolar space, or through the gaps left by teeth which have been lost. As a matter of fact there are few patients who are content with a liquid diet; they usually manage to consume crumb of bread, purées of all kinds, minced meat, etc.

. . . . . .

The mandible possesses yet other surgical advantages. In the case of a broken femur, for instance, it is not easy to operate directly upon the fragments without having recourse to an appliance such as a screw plate, Lambotte's splint, Lambret's apparatus, etc. The mandible is more amenable to treatment. The teeth present points of attachment which are exceptionally easy of negotiation, and, where the crowns are gone, the roots are probably still good. Thus, in addition to immobilisation, the surgeon is able to effect an almost mathematical reduction of the fracture. In the case of a fractured limb, length alone can be estimated with any degree of exactitude; other deviations, such as the angular, the rotatory, can only be approximately estimated. In the case of the mandible, a perfect and incontestable basis is provided by the dental adjustment. It may happen, however, that the teeth are missing. Occasionally they are entirely destroyed by the nature of the injury; sometimes the roots are so broken that extraction is the only possible course; or they may have been previously destroyed by dental caries. Finally, it may happen that the line of fracture passes beyond that part of the jaw which contains the teeth. Conditions such as these are very difficult to deal with, and they tax to the full the powers of both surgeon and specialist.

. . . . .

As we shall have occasion to show later on, the fragments of a fractured mandible do not, so far as we have been able to judge, present the phenomena of a

rarefying osteitis so frequently observed in fracture of the bones of the limbs. In both kinds of case pseudo-arthrosis is frequent. In the management of fractures of the bones of the limbs, lack of resistance of the fractured parts constitutes one of the chief difficulties. Their consistency is sometimes so attenuated that it is not possible to keep a metal plate in position by means of screws. It is necessary to attach it by means of ligatures, a far less efficacious method. This is a difficulty with which, in the case of the mandible, we have never had to contend. It seems rather that the extremities of the fragments undergo a species of condensation. The retention of properly adjusted screws has been perfect in the patients upon whom we have operated.

. . . . .

Such are the general considerations which we desire to present to those of our readers who are unfamiliar with the methods and results of stomatological therapeutics. That this volume contains so few references to the name of Claude Martin may to such readers appear surprising. It is not that we fail to appreciate the great achievements of the venerable scientist, who was a pioneer at a date when there was some merit in being one. But we feel that of his work, which was largely therapeutic, very little ought to be preserved. It could hardly be otherwise, seeing that in the last quarter of a century surgical methods have undergone a complete transformation, while, in the last two and a half years, an abundance and variety of clinical

material has come to hand such as Claude Martin never dreamt of. As we have already shown, his fundamental principle has not stood the test of facts. His object at all costs, even that of pseudo-arthrosis, was to preserve the dental adjustment. We have always supported the opposite view, namely, that in the vast majority of cases union of the fracture is the more important aim. Claude Martin's formula was : dental adjustment before mandibular rigidity. Our formula is : mandibular rigidity before dental adjustment. This view, which we were the first to advance, is the one adopted by the majority of surgeons and stomatologists.

But although the details of Claude Martin's work are becoming effaced by time, our admiration for the man who, first of all, perceived the necessity for the collaboration of the surgeon with the specialist must remain. Claude Martin was the first to face the problem of the re-establishment of the masticatory function after surgical intervention.

## CHAPTER II

### ETIOLOGY

FRACTURES of the mandible by instruments of war are usually comminuted. As a general rule they differ from those observed in civil life by loss of substance. It is, however, by no means exceptional to encounter war fractures in which there is no loss of substance, the injuries closely resembling those observed in civilian practice.

The etiology of the majority of cases is simple. The mandible is struck by a projectile which fractures it, producing fragments of varying size, which are either carried away by the projectile or are eliminated secondarily at the sequestration stage. It may happen, however, that the mandible is struck by a spent projectile, the force of which is exhausted by the shock of contact. In such a case the mandible is fractured, but either not, or only very slightly, splintered. Injuries of this nature we propose to describe as "fractures by contact," using the term in the sense in which it is employed to denote certain fractures of the cranium. In this class of case there is no loss of substance either primary or secondary, and the displacement is generally slight. Apart from the wound

there is nothing to distinguish these cases from those seen in general practice. The wound itself is unimportant, and cicatrises readily in spite of the presence of the projectile, whether a fragment of shell or a bullet.

It should be borne in mind that the accidents incidental to civilian life are not abolished in time of war. Fracture may be due to the kick of a horse, a fall, an earthslide, etc. In such cases the skin is unbroken, and, were it not for the injury to the mucosa, which is usually slight, the fracture would be a simple one.

## CHAPTER III

### PATHOLOGICAL ANATOMY

In a former work (*Presse Médicale*, 25, x. 1915) we divided the fractures of the mandible into two main classes :

1. Anterior fractures, the site occupying the median line or its vicinity ;

2. Posterior or lateral fractures, situated within a space bounded by the median line or its vicinity on the one hand and the angle of the mandible on the other.

To these two groups we propose now to add a third, namely, fractures of the vertical portion or ascending ramus of the jaw. The distinction may be regarded as a fine one, but we are of the opinion that it has a definite clinical and anatomical value. Fractures of the angle of the jaw resemble those included in group two, with this reservation, that they are invariably characterised by absence of teeth in the posterior fragment. Finally, there are cases of multiple and of comminuted fracture.

The basis of classification is by no means purely anatomical. Each of the main groups—namely, anterior fracture, posterior and lateral fracture, fracture of the ramus—possesses distinct clinical prognostic, and therapeutic characteristics.

The amount of substance lost varies considerably in each class. A loss of 1 to 2 cm. does not appreciably affect either the clinical appearances or the prognosis. Where the loss is large, however, very different conditions obtain, and these will be discussed later.

In all groups, both principle and secondary (fracture of the angle, multiple fracture), the continuity of the bone is broken and the fracture is described as "complete." In the case of the first two, fracture occurs between two groups of masticatory muscles. In the case of the third, it affects a portion of bone to which one group of these muscles is attached. Hence the functional derangement consequent upon fracture of one of the rami is not only different in character, but it is less grave.

In addition to these fractures, which, as they divide the bone into two parts, are termed "complete," there is yet another variety, obviously of minor importance, namely, the "incomplete" fracture. We propose to deal with this first.

## I. Incomplete Fracture

Incomplete fracture does not interrupt the continuity of the bone, though it may affect any part of it.

**Fracture of the teeth** is very frequent, and is usually a complication of complete fracture. Artificial replacement is the only method of dealing with the condition. It should be borne in mind that fractured roots do not unite, and, even where a tooth appears

to be sound, if the root is cracked, extraction is the only remedy.

**Fracture of the alveolar border** is common, and occurs frequently as a complication. There is a tendency on the part of the marginal fragment to bend inwards, probably as the result of attempts at mastication. Whether these fractures come under treatment or not, they invariably unite, with the consequent danger of malposition bringing the chewing surfaces of the maxillary molars over the external surfaces of the mandibular molars. At the beginning of the war such deformities were frequent. Now, however, that there is better provision for treatment they are rarely seen.

**Fracture of the inferior border** has little practical significance. Its presence is usually revealed by small detached splinters of bone which either unite or become sequestra.

**Fracture of the coronoid process** is very difficult of observation, and skiagrams give little help. The appearances resemble those of closure of the jaws.

**Fracture of the temporo-mandibular joint** is frequent and, the site of injury being immediately beneath the skin, it is easy of diagnosis. A patient who came under observation had in his possession the head and neck of the condyle, which had been eliminated as a sequestrum. He was able to perform masticatory movements without inconvenience. Closure of the jaw as the result of ankylosis suggests itself as a very possible complication, yet up to now no case has come

under observation. Except that lateral deviation and retrusion are more marked, the displacement of the fragments, where present, is precisely similar to that observed in fracture of the ramus.

**Perforation** is sometimes observed. In this case the projectile, usually a bullet, traverses the mandible without disturbing its continuity and produces a simple loss of substance. It is noticeable that, as in fractures of the cranium, the inner bony layer is more extensively affected than the outer, with the result that the sequestra are sometimes larger than the apparent loss of substance. The analogy, however, ceases here, these lesions having none of the gravity and urgency associated with those of the cranium.

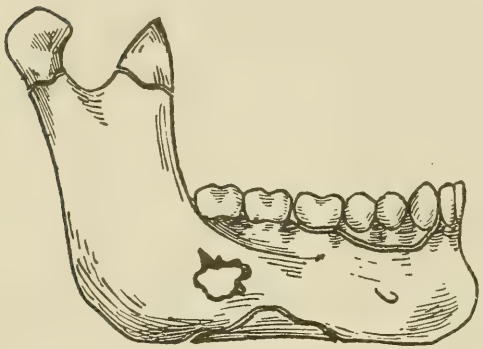


FIG. 3.—Different types of incomplete mandibular fracture; fracture of the upper or alveolar border; fracture of the lower border; fracture of the coronoid process; fracture of the condyle; perforation.

## II. COMPLETE FRACTURE

As we have seen, it is expedient to divide the complete fractures into three main groups.

Loss of substance is usual, but certain fractures occur which, as in the case of the cranium, we propose to describe as fracture "by contact," which are con-

fined to a simple crack. It must not be forgotten that, among the casualties of war, patients come under treatment with injuries resembling those seen in civilian practice, the originating cause being not a projectile, but a landslide, a kick from a horse, etc. The skin in these cases is frequently unbroken.

(*a*) **Anterior fracture** (median or paramedian).—The position of the fracture site is sometimes exactly median, that is to say, it passes between the two median incisors. It then deviates more or less to either the right or left, and a small triangular portion of bone is frequently detached from the lower border. In some cases the line of fracture passes between the two lateral incisors or between the lateral and the canine. In any event the displacement of fragments is so similar that the types are easily included in one group.

In median or paramedian fracture without loss of substance the deformity is so slight that, unless attention is drawn to it, the lesion may pass unnoticed. There is occasionally a slight vertical dental error, but as a general rule, and particularly where the fracture is single, there is no displacement in the horizontal direction. The vertical error usually undergoes spontaneous correction by contact with the upper row of teeth, and this class of fracture shows a distinct tendency to unite spontaneously in good position. It is fractures of this nature which are most frequently encountered in civil life, and this accounts for the fact that, in spite of the inefficiency of the retentive measures

in general employment before the war, treatment of mandibular fracture was not entirely unsuccessful.

In the surgery of war, however, loss of substance is almost invariably present, and, in the simplest cases, it corresponds to the loss of one or two teeth.

Let us take a typical instance (fig. 4). The missing

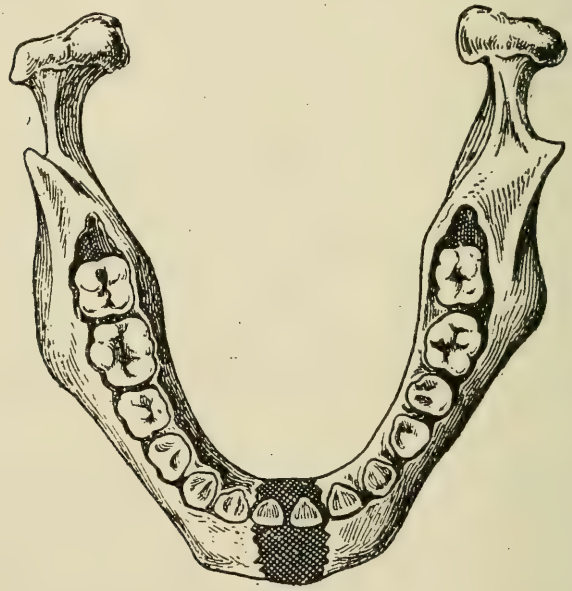


FIG. 4.—Anterior median fracture. Loss of bony substance equal to two incisors.

portion of bone includes the two median incisors, and the loss of substance amounts to 1 cm. The two fragments tend to approach one another. As they are of practically the same length, and are subject to very much the same influences, each portion performs half the journey, the fractured surfaces again meeting at the median line (fig. 5). The effect upon the interdental articulation will be described in detail later. Suffice

it here to say that in cases of this sort the derangement is very slight, the effect upon the molars being practically nil. It is more apparent in the case of the anterior teeth, where the natural tendency to retreat behind the corresponding teeth of the upper jaw is intensified (fig. 8).

Where loss of substance is very extensive, this cannot

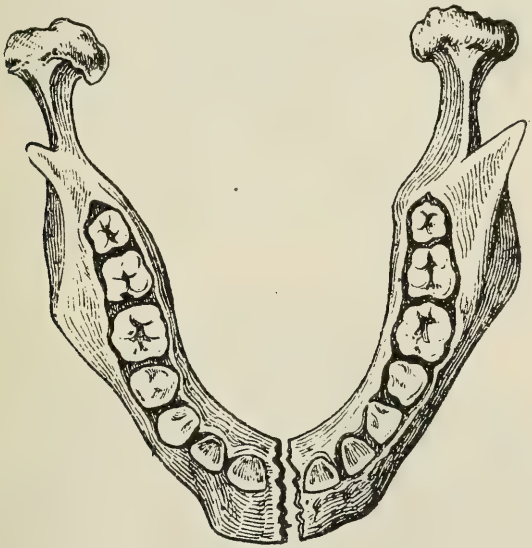


FIG. 5.—Displacement of fragments in the fracture shown in fig. 4. The union of the fractured surfaces produces a Gothic arch, the mandible assuming the characteristic serpent-form.

of course hold good. There is always a tendency on the part of the fractured portions to approach one another, but the mandible here takes on a triangular form (Sébileau's serpent jaw) which not only throws the front teeth very much behind those of the upper jaw, but also produces error in the molar articulation, with consequent functional deficiency.

FIG. 6.—Right paramedian fracture with moderate loss of substance.

FIG. 7.—Right paramedian fracture with moderate loss of substance. Loss of the teeth and alveolar border of the right side.

The tendency to approach one another, which is manifested by the fractured portions in injuries of this type, is so strong that unless the amount of substance lost is positively prohibitive, union is always effected. Cases have come under notice in which there was union, though with inevitable malposition, between two fragments, each of which contained only molars.

In paramedian fracture the tendency of the frag-

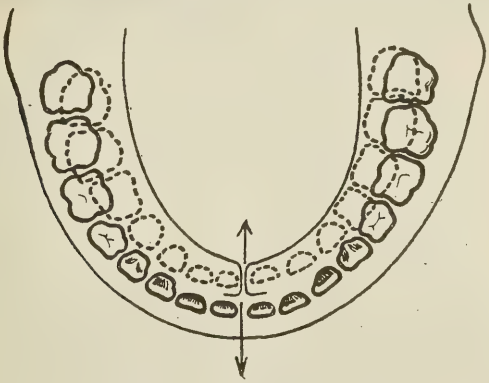


FIG. 8.—Anterior median fracture with loss of two incisors. The dental adjustment is only slightly disturbed. The median lines coincide; slight retraction of the inferior dental arch; slight displacement of the molars inwards. (The lower teeth are indicated by means of dotted lines.)

ments to unite without superposition is very marked. This tendency is common to all varieties of the anterior group, and constitutes the basis of classification. Where there is no loss of substance, deformity is slight, as in true median fracture.

Where there is slight loss of substance, the union of the two bony fragments takes place in the same manner. The disturbance of balance between the bony fragments and the forces which act upon them is

insufficient to produce overlapping. The surfaces come together in close contact, thus compensating for the absence of the intermediate bony structure. But the effects on the occlusion are naturally more important. The shorter fragment has no anterior teeth, but occludes satisfactorily with the upper teeth ; the larger fragment is considerably displaced, as shown in fig. 9, the left fragment deviating to the right to the extent of at least the width of an incisor tooth.

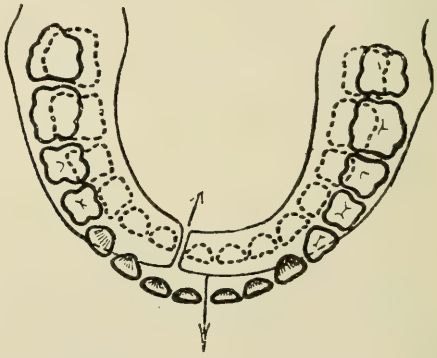


FIG. 9.—Paramedian anterior fracture. There is union without superposition similar to that in fig. 8. The left fragment being the longer, the median line is deflected towards the right fragment. (The lower teeth are indicated by means of dotted lines.)

The derangement of dental articulation, though somewhat more marked than in median fracture, is still compatible with efficient mastication.

Where the loss of substance exceeds two centimetres, the deformity becomes much more marked. This is due to displacement of the larger fragment, the position of the smaller fragment remaining practically normal. The teeth are more numerous in the larger fragment and their articulation is very faulty, sometimes as

faulty as in lateral fracture. The tendency to unite is appreciably less than in true median fracture, and pseudo-arthrosis is a fairly frequent occurrence.

(*b*) **Posterior or lateral fracture.**—The site of fracture varies from the canine to the last molar.

Even where there is no loss of substance, the dis-

FIG 10.—Left lateral fracture with considerable loss of substance. Contact is established by a bony bridge which proceeds from the posterior fragment and meets the anterior fragment.

placement of fragments in these cases is frequently so great that the last tooth of the larger fragment is behind the first tooth of the smaller. As a general rule, however, deformity is the result of an appreciable loss of substance.

Take the case of a mandible fractured on the right

side with loss of substance corresponding to one tooth, the second premolar, for example. The displacement of the fragments is quite typical, so much so that it lends a characteristic appearance (to be described later) to the face.

It is usually the larger of the two fragments, the

FIG. 11.—Right lateral fracture. Loss of substance corresponding to two molars. Union brought about by means of an apparatus after forward movement of the posterior fragment.

one bearing the median teeth, which undergoes the most marked displacement (fig. 12). It performs a sort of pivoting movement around a fixed point which corresponds approximately, though perhaps not actually, to the temporo-mandibular joint of the same side. The immediate effect of this movement is to push the middle teeth of the mandible backwards in

such a way that, when the jaws are closed, instead of touching the posterior surface of the maxillary incisors, there is a space between the two rows which is sometimes considerable, and may even amount to as much as a centimetre.

But this is not the only result of the pivoting movement. The middle incisors are thrown towards the fractured side, and although this result does not strike

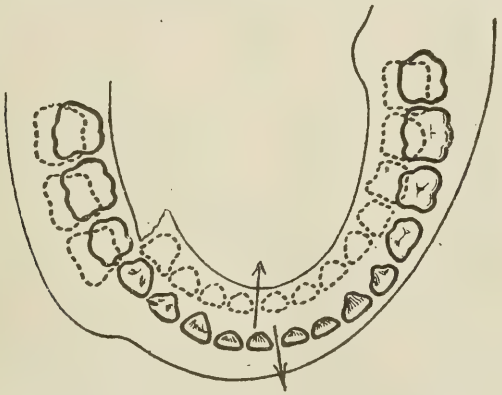


FIG. 12.—Lateral fracture. Union with superposition; retraction of the median line with deviation towards the fractured side.

one on casual observation it is none the less evident if careful examination is made. If the jaws are closed and the lips are raised, it will be seen that the median line, as marked by the interspaces between the central incisors, is not continuous in the two jaws. In the mandible it leans towards the fractured side (fig. 12). The deviation frequently amounts to the space of one tooth, the interstice between the inferior median incisors corresponding to that between the superior central and lateral incisors of the wounded side. The

error may be even greater still, and may amount to the space occupied by two incisors.

Recission of the middle teeth and deviation of the median line in the direction of the fractured side are the two most fundamental effects of the displacement of the fractured portions. The relationship between the bony fragments is, however, complex, and these are not the only results of displacement.

The pivoting movement, then, tends to bring the two fractured surfaces together, and in some measure to compensate for the bony substance lost. In a few instances perfect union is the result, the fractured surface of the larger fragment uniting evenly with that of the smaller, as it is sometimes seen in paramedian fracture. Perfect union does not exclude the two deformities described above with their attendant facial asymmetry, but it does exclude pseudo-arthrosis. Dental adjustment is imperfect, but mastication is quite possible, and the functional condition must be regarded as tolerable.

Such cases as these are, however, exceptional. As a general rule, lateral fracture with loss of substance is accompanied by marked superposition, similar to that seen in fractures of the leg and thigh. The superposition is from front to back ; the segments of the dental arch remain approximately upon the same plane ; and the end of the larger fragment is usually inside that of the smaller one (fig. 12).

What are the causes which tend to produce so constant an arrangement ?

The immediate cause would seem to be the pivoting of the larger fragment upon its condyle. The fractured surface thus describes an arc which takes it within, or sometimes without, the fractured surface of the smaller fragment. The question arises, why should it be the larger fragment and not the smaller one which performs pivoting movements, or at least performs them to a preponderating extent? The ultimate

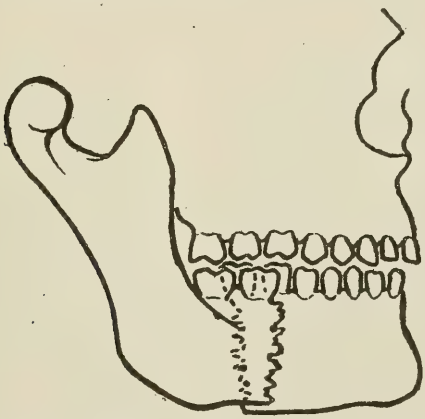


FIG. 13.—Lateral fracture. The posterior fragment is directed obliquely forwards, the obliquity being limited by the teeth which it contains.

cause of the movement seems to us to lie in the action of the muscles attached to the mental spines and the mylo-hyoid ridge. It is obvious that such action must exercise a preponderating influence upon the larger fragment.

Viewed in this light, it is easy to understand why the fractured extremity of the larger fragment is sometimes within and sometimes without that of the shorter fragment.

This, however, is not all. Superposition, whether slight or marked, is accompanied by lateral projection of the shorter fragment. The latter contains, or should contain, the inferior molars which become projected outwards. Where the lateral deviation is slight, the internal or lingual cusps of the inferior molars engage the intercuspidal hollows of the superior molars. Where the displacement is very marked,

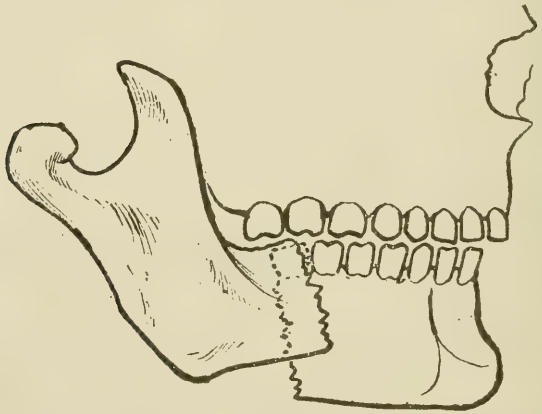


FIG. 14.—Lateral fracture. The posterior fragment is without teeth; its obliquity is more marked than that in fig. 13.

though this is rare, the inferior molars may pass quite outside the superior molars and fail to articulate with them at all.

The displacement of the larger fragment involves yet another issue which, though more difficult of observation, is none the less characteristic of lateral fractures, especially of those accompanied by important loss of substance: it determines the position of the smaller fragment.

As we have just seen, the smaller fragment is usually

driven outwards by the extremity of the larger fragment. It is also projected forwards in such a way that the posterior margin of the ramus, which with the subject in the upright position should be nearly vertical, becomes gradually more oblique, as shown in figs. 13, 14, 15.

In the case of a fracture such as that described, one, namely, in which the second premolar is absent, the

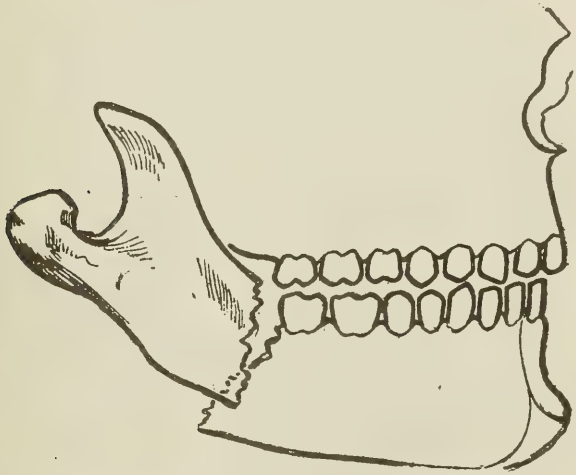


FIG. 15.—Lateral fracture. The line of fracture passes behind the molars; very marked obliquity of the posterior fragment.

other teeth being present in their entirety, the inclination from the vertical is slight. It could not become accentuated without altering in the vertical sense the dental plane of each fragment. Although the modification is slight, it is generally sufficient for the forward deflection of the lower border of the jaw to be appreciable. Where the smaller fragment is toothless (traumatism, previous dental caries), other conditions remaining the same, the degree of obliquity is greater

(fig. 14). It is still more accentuated where the position of the fracture is behind the last standing molar (fig. 15).

Where the loss of substance exceeds 2 cm., pseudo-arthrosis seems to be the rule. It is frequent, even

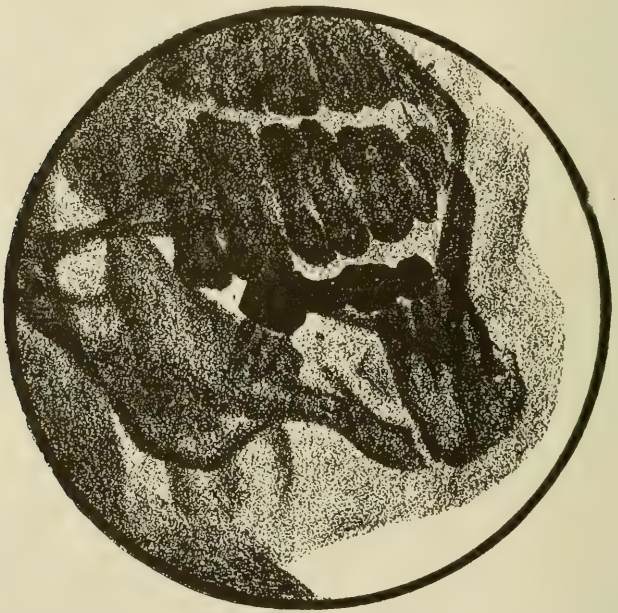


FIG. 16.—Left lateral fracture with large loss of substance. Contact is effected by means of a bony bridge proceeding from the posterior fragment. Fixation of the fragment by means of an apparatus. The illustration shows the bridge by which the fragments are immobilised.

in cases where the break in the continuity of the bone is comparatively small.

(*c*) **Fracture of the angle.**—These cases closely resemble those in class (*b*), with this distinction, that the smaller fragment is of necessity invariably toothless. Hence, therapeutically they constitute a separate

group; anatomically and clinically they belong to class (*b*).

(*d*) **Fracture of the ramus.**—These fractures are difficult of observation: first, because the seat of injury is concealed beneath a dense muscular mass; second, because the derangement of function to which

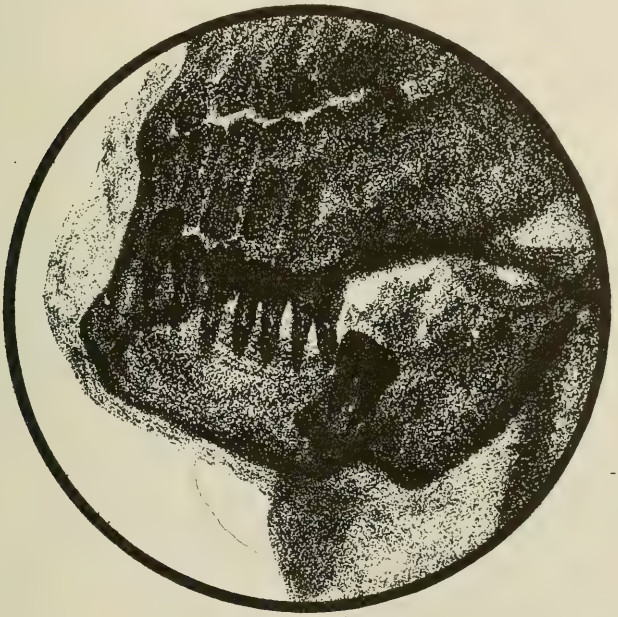


FIG. 17.—Right lateral fracture. Undeveloped third molar involved in the region of the fracture site.

they give rise is slight or even nil. As a matter of fact, we failed to recognise this particular injury for some months, and it was its apparent and incomprehensible rarity which led us to investigate the matter. We then discovered that it is far more frequent than we had imagined, its frequency being about the same as that of the other groups.

The teeth, valuable guides as they are in other classes of fracture, are useless or nearly so here. Hence it is much more difficult in cases of this sort to determine the exact nature of the injury and the nature and degree of displacement. Skiagrams are valuable aids, though difficult to obtain and also to interpret.

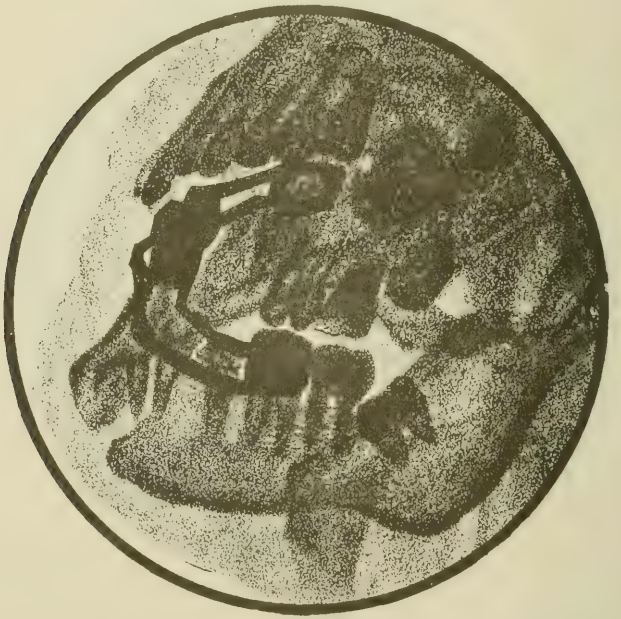


FIG. 18.—Right lateral fracture. Fixation by splint.

Fracture without loss of substance may occur in the ramus as well as in the body of the bone. These cases seem to progress simply without complications other than possible constriction. The fragments appear to be kept in place by the strong muscular bands which surround them, and there is no tendency to any marked displacement (fig. 20). Fig. 21 shows a possible dis-

placement of which up to now entire proof is not forthcoming. The two fragments are superimposed, the inferior being apparently outside the superior, the position resembling that seen in fractures of the following type.

Where there is loss of substance, a position very

FIG. 19.—Right lateral fracture with large loss of substance and numerous splinters. In process of union by immobilisation of the fragments in occlusion.

characteristic of the lower jaw is frequently though not invariably observed. The teeth of the fractured side are brought into contact with those above them, a condition which can only result from a union such as is shown in fig. 21*a*.

Do these fractures unite ? From the difficulty ex-

perienced in correcting malposition in old fractures we assume that they do, but it is not certain that union is invariable. Pseudo-arthrosis is difficult to diagnose, which suggests that it has little functional significance. It is possible that it occurs with some frequency, but, as far as our experience goes, operation is not indicated.

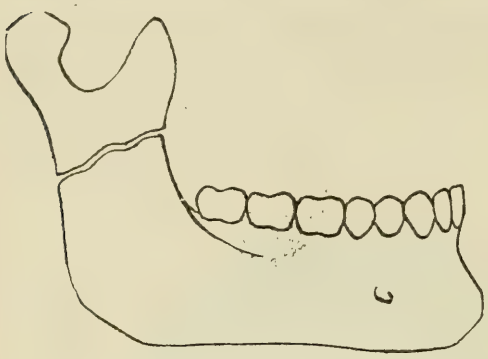


FIG. 20.—Fracture of the ramus without displacement of fragments or loss of substance. (This fracture does not in any way modify the shape of the mandible; its presence is not betrayed by any characteristic malposition; the subjective phenomena and skiagrams are the sole aids to diagnosis.)

(*e*) **Double and multiple fracture.**—These fractures are fairly frequent. In double fracture there may be

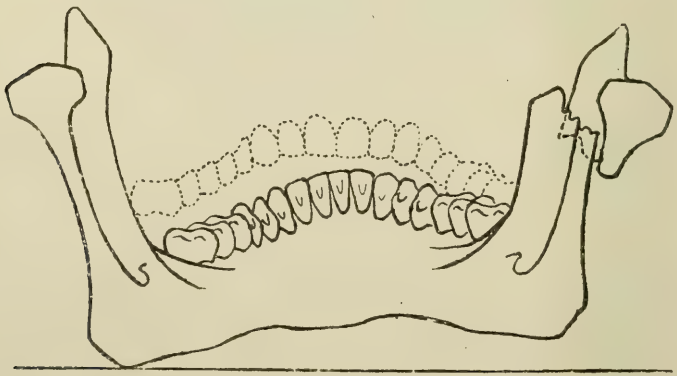


FIG. 21.—Fracture of the ramus with superposition of the fragments. (In fractures of this type the superposition of the fragments is accompanied by shortening of the ramus, which produces an error of occlusion.)

loss of substance at one or both fracture sites. A median fracture, or one included in the median line,

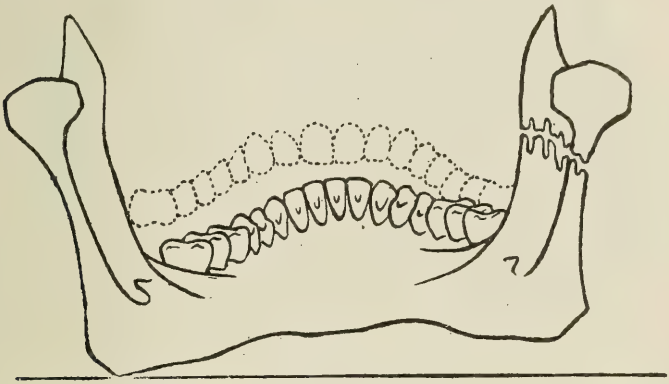


FIG. 21*a*.—Fracture of the ramus with loss of substance and subsidence of the fragments. (The loss of substance has been followed by the union of the fractured surfaces, the length of the ramus being thus decreased by the length of the bony substance missing. The shortening of the ramus is accompanied by inevitable elevation of the body of the bone on the injured side, which is shown in occlusion by the malposition represented in this figure. There is contact between the superior and inferior molars of the fractured side, and an interval between those of the sound side. This interval is greatest in the incisor-canine region.)

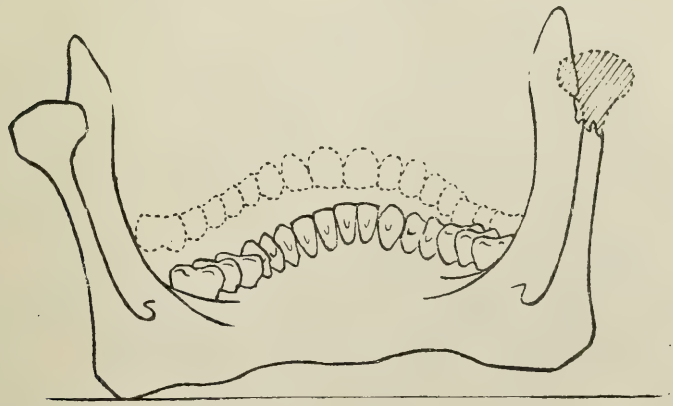


FIG. 22.—Loss of substance at the temporo-mandibular joint (This lesion is accompanied by shortening of the ramus and consequent elevation of the body of the mandible. Union produces a malposition in occlusion identical with that shown in fig. 21*a*.)

has a tendency to fall inwards. The consequent lingual displacement gives rise to dyspnœa, which has frequently been a cause of mystification to surgeons. Trachæotomy has been performed with regrettable frequency, in cases where simple traction of the displaced median fragment would have alleviated, or even abolished, the dyspnœa. The median fragment is occasionally displaced downwards.

Where the position of the median fragment is lateral there is also a certain tendency to fall towards the buccal cavity. But as often as not it follows the line of deviation of one of the other fragments, with which its relation is approximately normal.

### III. Large Loss of Bony Substance. Shattering

We have up to now dealt exclusively with the specific characteristics of mandibular fracture in which the loss of substance does not exclude 2 to 3 cm. But there is a large class of case in which the loss of bony substance is far more extensive, the mandible being sometimes completely shattered. This class comprises two groups; those in which the injury is in the body of the bone, and those in which it is in the rami.

In a comparatively large number of cases the entire dental arch, together with its bony support, is missing. The fragments of the mandible still show a tendency to unite, but their small dimension renders this barely appreciable. The lesion is almost invariably accom-

Lateral fracture of the mandible. (Skiagrams. Direct reproduction.)

panied by considerable deficiency of the soft parts, with more or less complete suppression of the lower lip, and permanent salivary discharge.

Other cases are those in which the ramus, together with the angle and a more or less important portion of the dental arch, is missing. Here the injury is less serious, a certain number of teeth being preserved. The conditions somewhat resemble those seen in lateral fracture. In these cases the remaining portion of the mandible deviates towards the site of injury. The deviation is accentuated by the fact that a larger proportion of the horizontal part or body of the bone is involved in the fracture.

### IV. Large Loss of Substance of the Soft Parts

Gunshot injuries of the face are usually accompanied by more or less loss and laceration of the integument and soft parts. The study of such conditions forms no part of the object of this book. It should be kept in mind, however, that the degree of infirmity may be sensibly increased by the association of these lesions with those of the bony parts.

### V. Anatomical Development

In common with all fractures, those of the mandible terminate in either union or pseudo-arthrosis.

The length of time required for union varies considerably. As a general rule it is shorter in simple than in compound fracture. The vast majority of man-

dibular fractures, even where due only to contusion, are compound, and where there is no wound of the integument there is usually injury to the mucosa. Occasionally true simple fracture of the mandible is seen, no wound being present in either integument or mucosa. In cases of this sort the bony displacement

FIG. 23.—Double bilateral fracture with median third fragment.

must be either very slight or nil. It is our experience that even the small wound in the mucosa, by which fracture of the jaw without loss of substance is almost invariably accompanied, appreciably hampers the union of the bony fragments.

With rare exceptions all fractures without loss of substance unite. Muscular intervention seems to be

a negligible factor. Dental lesions, on the contrary, have considerable importance. Union is sometimes hindered by the presence of a root, especially if broken or carious, and more than once union has been effected by the simple expedient of extracting one or two teeth. Union of a simple fracture, or of a compound

FIG. 24.—Right lateral double fracture with intermedial fragment.

fracture with the wound in the mouth, without loss of substance, is usually effected in between two and three months. Pseudo-arthrosis has not been observed in cases such as these.

In the case of comminuted fractures with loss of substance the clinical conditions are obviously very different. A much more important part is played here

by accessory conditions (teeth projected into the fractured part, splinters in the sequestration stage). Operation invariably reveals a kind of fibrous callus between the fragments, which is probably due to intervention of the soft parts, and is a cause of the pseudo-arthrosis. But it is the shape of the broken surfaces which seems to supply the chief factor in promoting pseudo-arthrosis. In the cases which come under operation, the fractured ends are almost invariably pointed.

The progress of these fractures is a subject we shall return to later. For the moment it is sufficient to state that union may take place in one of two ways. In some cases the fractured surfaces come together, with consequent effacement of the fracture site and formation of a bony callus. This is undoubtedly the better process, and it should be promoted wherever possible. In certain other cases the loss of substance seems to be made good spontaneously, doubtless by ossification of the periosteal laminæ which have remained intact. But favourable results are hardly to be expected except where the loss of substance is slight. Spontaneous union occurs more readily in median than in lateral fractures, and this should be borne in mind where operation is contemplated.

Where there is loss of substance, union appears to be appreciably slower. Such fractures take at least three months to unite.

Pseudo-arthrosis is fairly frequent. We must, however, define exactly what is meant by the term "pseudo-

arthrosis." Retarded union is not infrequent, and is almost invariably due to faulty methods of treatment. By means of a simple appliance we have succeeded in effecting a union in the case of fractures six months old or older. Pseudo-arthrosis cannot be regarded as a permanent condition until the fracture has been

FIG. 25.—Left comminuted fracture. (The two lateral fragments involve, one the alveolar border, the other the lower border. Union is accomplished by apparatus.)

under suitable treatment for a period which, to include exceptional cases, we propose to fix at six months. It must be considered, not in regard to the age of the fracture, but in relation to the results of a reasoned treatment, methodically pursued over a period of six months.

The arrangement of the fragments has the same significance in pseudo-arthrosis as it has in recent fracture. In neglected cases the displacement is frequently exaggerated, but where treatment has been carefully and methodically pursued, the broken extremities, though separated by a varying interval, will face one another. They are quite solid, the bony canal being filled with a dense, compact, and resistant tissue. The extremity of the larger fragment seems, as a rule, to be the more bulky. The fractured surfaces are irregular, and are usually more or less pointed in shape. They are always united by a fibrous band possessing considerable resistance, a sort of fibrous callus, to which we shall have occasion to refer later, when dealing with the subject of surgical intervention.

## CHAPTER IV

### SYMPTOMS AND DIAGNOSIS

THE symptom-complex varies with the period at which the case comes under treatment.

All mandibular fractures pass through certain definite stages of development.

During the first stage, which lasts for a few days only, treatment must mainly centre around the preservation of life, for it is at this period that serious complications are likely to arise, such as infective conditions, dyspnœa, etc. At the second stage the fracture is termed " recent " ; the work of reconstruction is not begun but the ground is prepared for it. The minimal duration of this stage is one month, its maximum two. At the third stage the fracture is termed " old." This is the really active stage of treatment. Its duration may last for six months or even for a year after the date of injury. The fourth stage comprises the treatment, if present, of pseudo-arthrosis and malposition.

Fracture of the mandible is frequently accompanied by considerable damage to the face. Large wounds such as these are naturally liable to every kind of complication. Moreover, cases of this kind are frequently the subject of ill-judged intervention, the

results of which are a source of grave anxiety to the surgeons to whom the cases are ultimately referred. It may to a certain extent prevent repetition if we briefly enumerate these erroneous methods of procedure.

Every one knows, if only as the result of earlier researches in connection with resection of the mandible, that extensive loss of the median portion of the bone, or double fracture with a median third fragment, is accompanied by the falling of the tongue into the pharynx. This is due to the abolition of the points of attachment of the genio-glossal muscles. Yet in cases such as these, trachæotomy is frequently performed with the idea of relieving the dyspnœa or preventing asphyxiation. Such a proceeding cannot pass uncondemned. The obvious method is to pull either the fragment of bone or the tongue forward and so clear the air-passages. The result may be rendered permanent by means of a thread fastened either in the integument or in the ear. It must be borne in mind, however, that where dyspnœa is due to the presence of a foreign body, œdema of the glottis, etc., this method is quite useless.

Sébileau has protested very strongly against these trachæotomies, the gravity of which he emphasises. He also points out that in some instances gastrostomy has been performed. This operation can never be indicated except where all instruments for œsophageal catheterism, such as drains and œsophageal sounds, are lacking.

It was a common practice at the beginning of the

war to suture the flaps at an early stage, with the object of obtaining quicker and better repair of the wound. There has been a growing tendency on the part of surgery to discourage this practice. All surgeons with a war experience insist upon the absolute necessity of opening up all the passages, or, at least, of not closing them. This principle seems particularly applicable to injuries of the face, where the wounds almost invariably communicate with the buccal cavity which is naturally septic. These wounds should on no account be sutured on the skin side. On the other hand, it seems very expedient that wounds of the mucous surface should be sutured as soon as possible. Their restoration is not attended by troublesome after-effects, it has the advantage of eliminating a channel of infection, and at the same time facilitates any plastic operation which may be in contemplation. It has but one drawback—it is so rarely successful.

Although infective complications are undoubtedly facilitated by untimely intervention, these may also make their appearance in the case of wounds which have received appropriate treatment. Before and at the commencement of the war, surgeons insisted upon the frequency of septic troubles as well as upon their gravity. Now, however, such conditions are observed in very few cases, and when they do arise, continue for only a short period. The benignancy of wounds of the face is very generally recognised by surgeons attached to base hospitals, into whose hands patients are passed within an average period of four-

teen days from the date of injury. In our own service, the number of patients frequently exceeds 150, yet in eighteen months only one has died. In this instance death was due to general exhaustion consequent upon the rigours of the campaign rather than to a true septicæmia. Many of our colleagues, with a number of patients in excess of our own, have been still more fortunate and have not reported a single death. It has been observed from the beginning of the campaign that gas gangrene, which has had such terrible and far-reaching results in fractures of the limbs, does not occur in connection with wounds of the face.

Apart from general infective complications, local infections of the respiratory passages are also observed. If we are to believe the older text-books, these were formerly alarming in character and of considerable frequency. These local troubles may be occasionally observed at front-line stations; they are quite exceptional at the base.

The same observations apply in the case of secondary hæmorrhage, which occurs in connection with lesions of the face as of other parts, and which is undoubtedly of septic origin. It is liable to occur during the first few days. The suddenness of its onset, together with the impossibility in most cases of foreseeing it, constitute a grave source of danger.

All these complications are of septic origin. They may occur in connection with all traumatic wounds of the face, but their frequency is slightly greater in mandibular fracture.

## I. Recent Fracture

After the first period is over and septic complications are no longer to be feared, the symptoms of fracture should be carefully investigated.

**Abnormal Mobility.**—Of the two symptoms which are pathognomonic to fracture, that of abnormal mobility alone has a diagnostic significance in fracture of the mandible. Crepitation is invariably absent in fracture with loss of substance; in simple fracture it is difficult to obtain. Where obtainable its production causes great pain to the patient, and is liable to lead to further lesion of the soft parts, especially the mucosa. In fractures of the body of the bone, abnormal mobility is sufficiently characteristic to constitute a diagnostic sign. This is not the case in fracture of the ramus.

The method of determining abnormal mobility varies with the position of the fracture, whether anterior or lateral. Figs. 26 and 27 show the methods of obtaining the sign.

In median and paramedian fracture each portion of the mandible should be firmly held between the index finger and the thumb with the index finger uppermost, and the fragments should be moved one against the other. In posterior fracture, let us say of the right side, the left thumb is introduced into the mouth and pressure is exercised upon the teeth behind the fracture site, while the angle of the jaw is firmly grasped by the other fingers of the same hand. The right hand supports the other side of the jaw and

both hands endeavour to elicit movement at the site of fracture. Where the site of fracture is behind the last molar, the thumb is planted firmly upon the anterior border of the ramus.

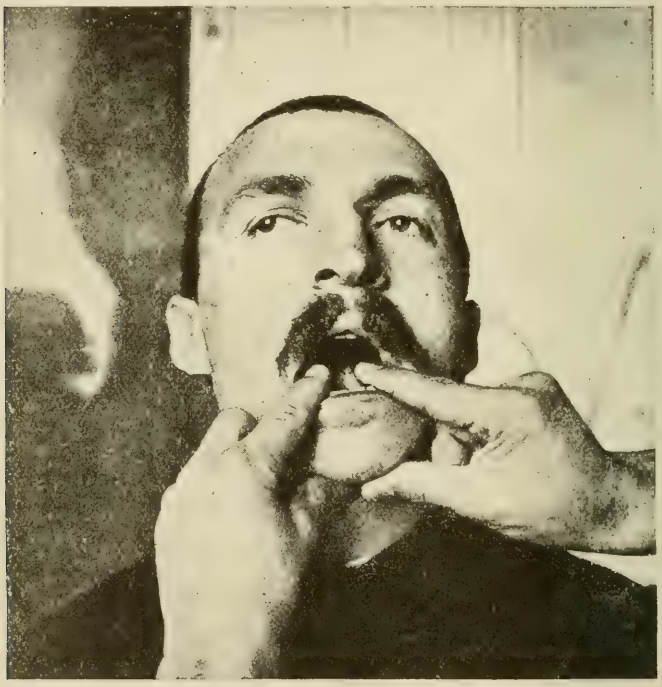


FIG. 26.—Showing method of examination for mobility in anterior fracture (median or paramedian). The two fragments are grasped by the thumb and index finger of the two hands and an attempt is made to move them one against the other.

As in the case of all fractures, slight mobility is not always easy of verification. When the teeth are all present the slightest movement between neighbouring teeth is apparent to the eye. But such a state of things is exceptional. The absence of several teeth

is the rule, and the sign is usually only perceptible to the touch. Opinions are not always in accord, especially as to whether or not the fractured portions have united. But these cases are exceptional, and, especi-

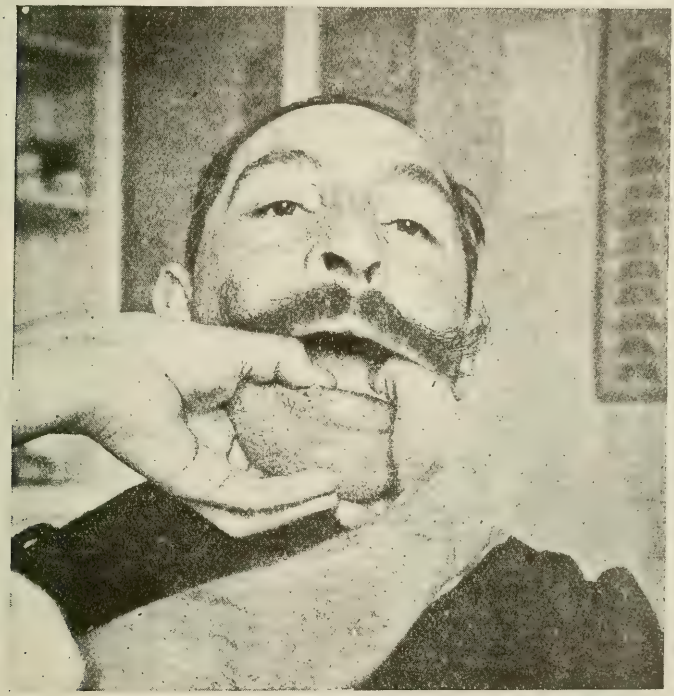


FIG. 27.—Showing method of examination for mobility in lateral fracture. The thumb of one hand is introduced into the mouth and is firmly planted upon the posterior fragment, which is supported by the fingers of the same hand. The anterior fragment is held in the other hand. An attempt is made to elicit movement at the fracture site.

ally where there is loss of substance, abnormal mobility is a diagnostic sign which is as a rule easy of verification.

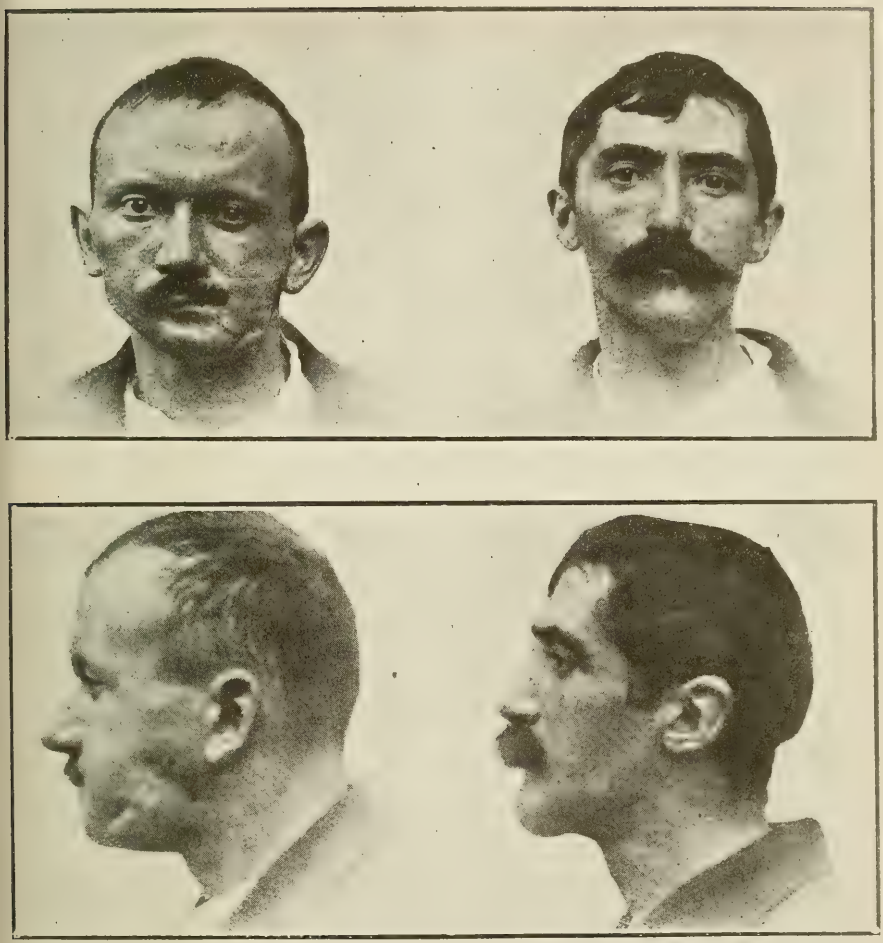
In fracture of the ramus, however, this sign is usually absent and diagnosis is consequently very difficult.

Skiagrams when clear constitute the sole method of diagnosis.

**Malocclusion.**—Fracture with loss of substance is invariably accompanied by a certain degree of malocclusion. The malocclusions accompanying different types of fracture have been described in a previous chapter. The principal characteristics may be briefly summarised as follows :

1. In anterior fracture the fragments are in contact without tending to overlap. The dental arch is therefore narrowed, and tends to assume a pointed shape (reptilian jaw). The apex of the arch is consequently distal to the upper incisor teeth. The lower side teeth become internal to the upper side teeth. The deformity is more accentuated in the front than in the back of the mouth. In paramedian fracture, the whole of the teeth of the sound side tend to be displaced towards the fracture site, the displacement corresponding to one or two, or even more, teeth.

2. In lateral fracture the deformity is more complex. The long fragment inclines towards the fractured side, the median line being diverted in the same direction. Its extremity is usually inside the shorter fragment, which moves forward to compensate for the loss of substance. Owing to the fact that the shorter fragment is practically fixed at the level of the temporomandibular joint, this movement can only be accomplished by elevation of the fractured extremity (figs. 13, 14, 15). This elevation is more or less pronounced according to the number and position of the remaining



Lateral fracture of the mandible. Photographs show the full-face and the profile of the fractured side. Deviation of the chin towards the fractured side. The face on the same side appears shortened. The skin is elevated by overriding of the fragments. There is frequently a cicatrix. The sound side appears prolonged and flattened, without a cicatrix.

teeth of the fractured side. It is particularly marked in certain fractures of the angle.

3. The deformity accompanying fracture of the ramus is characterised by malocclusion of a characteristic type, the teeth of the fractured side meeting while there is still an interval between those of the sound side (figs. 20, 21, 22).

In fracture without loss of substance the displacement of fragments is very slight or nil. Occasionally it appears more marked, but this is only apparent, and is due to the malposition of teeth partially loosened from their sockets, or to alveolar fracture. Where the displacement is real, the teeth of one fragment will be displaced in either the vertical or horizontal plane. In either case correction of the deformity is usually simple.

The symptoms of double fracture are easily recognised by the methods described. There is characteristic displacement of the mobile fragment. It tends to drop downwards and to remain loose, with the result that, in occlusion, when the posterior teeth are in contact the anterior teeth are separated by a gap of two to three millimetres. Fractures of this kind may easily unite in malposition.

**Facial Asymmetry.**—In the *Presse médicale* (25. X. 1915) we published an account of the facial asymmetry characteristic of different fractures of the mandible. It is most pronounced in lateral fracture. The features of asymmetry are usually sufficiently marked to reveal at a glance the nature of the lesion. This

applies also to cases in which union has long been effected. The characteristic signs of asymmetry are as follows :

1. The median line, with the chin, is deflected towards the fractured side. The deviation is very apparent and has the effect of emphasising the sound

FIG. 28.—Zones of anæsthesia in fracture of the body of the mandible.

side, which, in comparison with the other, appears prolonged and more prominent.

2. The fractured side presents a degree of tumefaction which corresponds to the fracture site and is due to the presence of the callus, displacement of fragments, etc.

3. The prominence of the angle of the jaw of the

fractured side is abolished. Displacement of the smaller fragment causes the posterior border of the bone to slope forward, with the result that in profile it appears flattened and retreating.

4. The skin in the neighbourhood of the fracture is usually disfigured by a cicatrix of varying importance.

**Cutaneous Anæsthesia.**—We have shown, with Gauthier and Lheureux, that anæsthesia of the chin is a certain sign of fracture of the mandible. It is particularly useful in old cases where union has taken place some time previously and where retrospective diagnosis is difficult.

This anæsthesia is of course due to section of the inferior dental nerve, either in the canal or immediately in its vicinity. It is not observed in median and paramedian fracture, nor in fracture of the ramus when this is situated above the opening of the inferior dental canal. It seems, however, to be constant in lateral fracture. The zone of anæsthesia occupies a practically circular area upon the chin of a diameter of three to four centimetres, and this is prolonged on to the corresponding region of the lower lip. It frequently happens, though this is not a constant sign, that there is anæsthesia of the mucosa of the cheek and of the external gum as far as the fracture site. Insensibility of the inner gum is occasionally observed, but we have found it a very inconstant sign.

[1] It should be borne in mind that the continuity of the sensory nerves is sometimes interrupted by cicatrices. Hence irregular areas of anæsthesia arise, and these are liable to be confused with the results produced by section of the mental nerve.

There is of course anæsthesia of the teeth up to the median line. This is readily tested by means of a thermo- or galvano-cautery. Sharp pain results from its application to the teeth of the fractured side, while those of the sound side do not react.

Examination for abnormal mobility is usually accompanied by little pain in mandibular fracture. The explanation lies in the lack of sensibility of the anterior fragment.

## II. Old Fracture

Except in regard to modifications brought about by union or by methods of treatment, the signs of old fracture are similar to those of recent fracture.

Where there is pseudo-arthrosis, abnormal mobility is usually very marked and may be readily obtained by the methods described.

Malocclusion and facial asymmetry are more or less pronounced according to the results of treatment. In the case of old fractures which have not come under treatment (such are still occasionally met with), the deformity, independently of union, resembles that of recent fracture. In such cases methodical treatment, though it may not effect a union, almost invariably succeeds in getting the larger fragment into good position. Occlusion of the major portion of the dental arch is thus established, and the chin is brought into the median line. The asymmetry affects only the smaller fragment, which retains its oblique and receding attitude, the teeth where present interdigita-

ting more or less imperfectly with those of the upper jaw.

Anæsthesia in the vicinity of the mental nerve seems to be constant. It is present in the oldest fractures independently of union. And it is unaffected by the results of osteo-synthetic intervention. For these reasons it constitutes a reliable retrospective sign in mandibular fracture.

Old fractures are frequently complicated by sinuses. These as a rule are not deep, and lead either to a centre of necrosis, sequestrated or not, or to an osteitic cavity. All surgeons know how tenacious and persistent these sinuses are when they occur in connection with fracture of a long bone, especially the femur. To close them requires the most minute and prolonged care. Such is fortunately not the case in sinuses about the mandible. If the passage is well opened up and curetted, healing is certain to follow. The curette frequently brings away fungoid growths, small sequestra, the root of a tooth, or even a tooth itself displaced at the time of injury by the projectile.

Facial paralysis is frequent in both old and recent fracture. We have made no searching investigation, but it is safe to say that spontaneous recovery is frequent.

### III. Fracture of the Angle

This variety is closely allied to lateral fracture and presents similar appearances: abnormal mobility, facial asymmetry, malocclusion. Separate classifica-

tion would not be necessary were it not that the condition presents a characteristic therapeutic difficulty. Owing to the fact that the site of fracture passes behind the last molar, the posterior fragment is invariably without teeth. Consequently it is not possible to apply prothetic mechanisms by the usual methods. Hence the classification is therapeutic rather than clinical. Surgical intervention has never in our experience been indicated. Unless there is large loss of bony substance, these fractures unite readily under mechanical treatment.

### IV. Fracture of the Ramus

The frequency is about the same as in the other classes of fracture, but the principal signs are absent and diagnosis is consequently more difficult. On the other hand the deformity, once its nature is recognised, is very characteristic. On closure of the jaws the teeth of the fractured side come into contact with those above them, while the teeth of the sound side are still separated by an appreciable interval (see p. 611 *et seq.*). The condition can only be accurately diagnosed by means of skiagrams.

### V. The use of Radiography in Mandibular Fracture

As in the case of all the curved bones, radiography presents special difficulties. The parts most difficult of observation are the anterior or mental portions, and the highest part of the ramus, namely, the condyle.

It will be seen, however, that in the majority of our skiagrams the ramus, the condyle, and even the coronoid process are all well shown.

Skiagrams of the lateral branches and of the lower portion of the vertical branches give valuable results. It is of course necessary to take a separate picture of each side. The secret of obtaining successful pictures lies in taking the mandible at a very oblique angle, in such a way that the part of the bone which is not in contact with the plate is pushed as far back as possible and does not obscure the image which it is desired to obtain. This result is not always obtainable, the two images sometimes appearing in a certain degree of juxtaposition. Such proofs are very difficult to interpret. For this reason a few hints on the management of skiagrams in mandibular fracture will not be out of place.

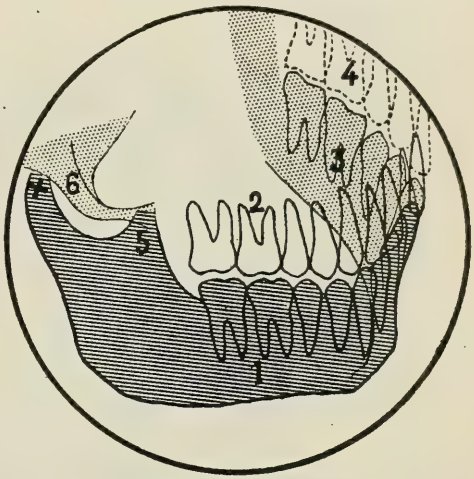



FIG. 29.—Diagram showing the method of interpretation of skiagrams of the mandible. The skiagram is intended to show the left side of the bone. (1 and 2, superior and inferior rows of teeth of the left side; 3 and 4, rows of teeth of the right side—by the obliquity of the rays these latter are removed as far as possible from the image of the left side; 5, left coronoid process; 6, left condyle. The latter is marked with a cross, which is reproduced, and serves as a guide in skiagrams of mandibular fracture.)

Fig. 29 is a reproduction of a drawing from a skiagram obtained under the most favourable conditions. It shows the outline of the left side of the bone. The condyle and its neck, as well as the coronoid process, are clearly seen. But results are by no means always

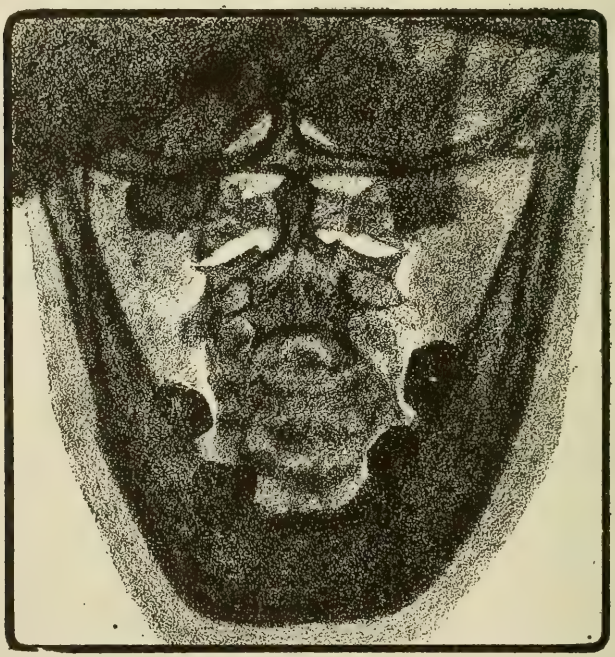


Fig. 30.—Skiagram obtained by application of the full-face to the plate.

so happy. Where there is insufficient obliquity of the rays these parts, as well as the ramus, are more or less confused with the image of the ramus of the opposite side. Or, as sometimes happens, they are obscured by the details of the cervical vertebræ. And it must be borne in mind that, even in cases where a sufficiently clear image is obtained, the

obliquity of the rays sensibly deforms the outline of the upper portions of the bone.

The X-rays successively encounter the dental alignment of the right side and of the left, hence four rows of teeth should appear in the picture. The two lower rows represent the superior and inferior teeth of the side nearest to the plate. This image is the clearer and it is the one which it is desired to obtain. The two upper rows represent the image, or rather the radiographic shadow, of the upper and lower teeth of the side furthest removed from the plate. This is the image which it is not desired to obtain. The obliquity of the rays should correspond exactly to the distance from the field at which it is desired to place the second image. The excellence of the skiagram depends upon the lack of clearness of the second image and its distance from the first. In a bad picture, both images are projected at approximately the same point, the outlines which should be separate thus becoming confused. The difficulties of the method should not be allowed to be a cause of discouragement, for in mandibular, as in other fractures, good skiagrams are valuable diagnostic aids

## VI. Closure of the Jaws

Closure of the jaws is perhaps the most frequent complication of wounds of the face, but as far as our experience goes it is infrequent in mandibular fracture and particularly so where the fracture is complete.

In another place we have described a hypermyotonic form which is very common. In our experience it includes four-fifths of cases. Its characteristics are: The comparative insignificance of the wound, which is sometimes unaccompanied by even incomplete fracture; the fact that, by the method described,

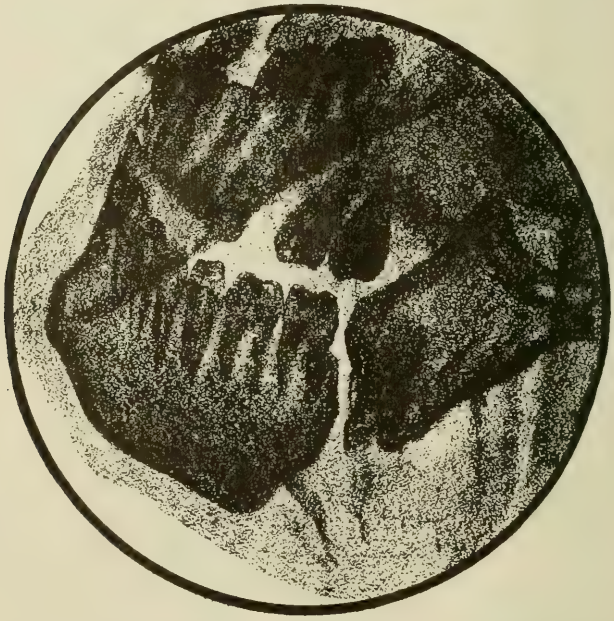


FIG. 31.—Fracture of the angle, right side. Marked obliquity of the posterior fragment.

the mouth may be opened at one sitting; and the precipitate nature of the condition, the mouth shutting immediately upon injury. As a matter of fact this form of closure, though frequently accompanying

[1] La constriction des mâchoires par blessures de guerre, Académie de Médecine, February, 1916. *Presse médicale*, August 24th, 1916. Interallied Dental Congress, 1916. *Presse médicale*, February, 1917.

mandibular fracture, does not seem to be caused by it. The same applies to the cicatricial form, which is the outcome of more or less important destruction of the soft parts.

The presence of fibrous bands in the subcutaneous and submucous structures is another cause of closure

FIG. 32.—Fracture of the ramus, right side.

of the jaws. In some instances these are due to prolonged superficial cicatrices with sclerosis affecting either the temporal muscle or the masseter. More frequently a more or less resistant area, which is sometimes very rigid, is observed beneath the buccal mucosa. This it is which prevents the depression of the mandible.

But all these forms of closure are present in mandibular fracture solely as complications of accessory lesions of the soft parts. In closure arising from ankylosis of the temporo-mandibular joint, however, the case is otherwise. It is readily conceivable that injury to this joint and to the bony masses in its

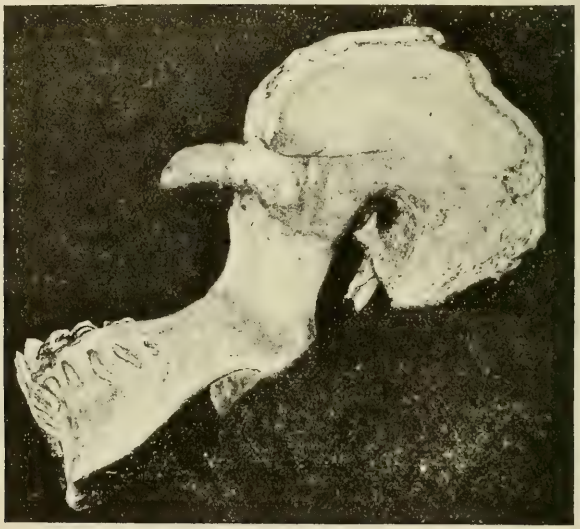


FIG. 33.—Complete ankylosis of the temporo-mandibular joint. Post-mortem specimen from a man who had suffered violent traumatism many years previously. The dental arch of the same side was bent inwards; the other temporo-mandibular joint, immobilised at the same time, was quite normal.

vicinity may, as in the case of other joints, provoke ankylosis by union of the articulating bony surfaces. Such a condition among patients of war has never been observed by us. One case, however, came under notice, that of a civilian. The patient was a young man of twenty who was brought to the Hôtel-Dieu

at Marseilles with a gunshot wound in the dorso-lumbar region. There was injury to the cord with paraplegia. At the time when he came under observation the injury was several months old and his general condition forbade surgical intervention. Now for several years this man had suffered from absolute constriction of the jaws. The mandible was incapable of performing the slightest movement, either active or passive. Nevertheless long habit, together with the absence of several teeth, had allowed him to assimilate his food, and his general development was absolutely normal. He had even formed one of a gang of Marseilles roughs, and his unlucky star alone was responsible for an " accident " which doubtless made of the aggressor a victim. The photograph shows the condition of the joint after death ; ankylosis was complete. From what we could afterwards learn, the lesion was the result of a fall from a height in childhood. It is an interesting fact that the other temporo-mandibular joint, in spite of its long immobilisation, was entirely normal.

We have had no personal experience in the treatment of this form of closure. For information concerning the operative measures which are indicated in the condition, we cannot do better than refer the reader to the writings of Ombrédanne.

### VII. Clinical Development

The details of this subject have been largely dealt with in the chapter on pathological anatomy. Clinical

progress in mandibular fracture terminates normally in union, with more or less malposition according to the amount of substance lost. The question of sinuses has already been discussed.

(*a*) **Pseudo-arthrosis.**—As we have already pointed out, and shall again have occasion to repeat, pseudo-

FIG. 34.—Left lateral fracture with large loss of substance. Permanent pseudo-arthrosis.

arthrosis is not established until mechanical treatment has been pursued for some considerable time. A period of at least six months should be allowed. Occasionally, however, as in shattering of the mandible with large loss of substance, no known therapeutic measure is able to overcome it and it must be regarded as inevitable.

In the case of the jaw, pseudo-arthrosis does not

possess the absolute functional significance only too frequently attaching to it in connection with fracture of the long bones. Nevertheless the degree of incapacity which it is able to produce is frequently considerable. In simple pseudo-arthrosis, where the loss of substance is not very extensive, performance of

FIG. 35.—Left lateral fracture with large loss of substance. Mechanical treatment resulted in slight pseudo-arthrosis with good occlusion.

function is still possible though it is naturally very imperfect. Mastication of hard substances is impossible, but all soft foods, such as crumb of bread, tender, well-cooked meat, etc., can be consumed. Where, however, a large proportion of the dental arch is missing, and even where only half the mandible is out of play,

mastication is practically impossible. Only food in a condition fit to swallow should be introduced into the mouth. Trituration is a function of the tongue, and, as may be readily imagined, its performance in this direction is very much reduced.

From the functional point of view, then, there are degrees of pseudo-arthrosis. That this is also the case in regard to treatment we shall see later.

(*b*) **Types of Malocclusion observed in United Mandibular Fracture.**—The various types of malocclusion which follow union in mandibular fracture are associated with deformity in varying degree. These deformities reproduce the characteristic bony displacements which, not having been reduced by clinical methods, have become fixed.

Median and paramedian fracture are followed by mandibular atresia due to linguo-version of the fragments. Lateral fracture and fracture of the angle are followed by lateral deviation and retraction of the larger fragment, with displacement above, in front of, and outside the posterior fragment. Faulty union of the ramus may be revealed by an interval on closure between the teeth of the sound side, with slight retraction. These are definite anatomical lesions, and correction of the malocclusion associated with them is only possible where the normal shape and orientation of the jaw can be restored by surgical or mechanical means.

Where the callus, as shown by skiagrams, has not undergone complete ossification, mechanical measures

should yield the best results. The mechanisms, to be described later, are similar to those employed in reducing old fractures.

If the callus has undergone ossification, correction of the deviation can be obtained only by surgical means. The most favourable operation is undoubtedly oblique osteotomy, so frequently employed in the surgery of the limbs. We ourselves have never had occasion to employ it, but it ought to be attended by excellent results in cases such as these. It has frequently been employed with satisfactory results by Sébileau. The oblique incision permits the separation of the two fragments, the angular extremities being kept together by means of a plate. The immobilisation thus obtained is reinforced by a mechanism attached to the teeth, which re-establishes the normal occlusion. In addition to the malocclusions due to serious bony lesion, there is yet another form the pathology of which is complex and its symptomatology entirely specific.

This type of malocclusion is seen after fracture of the horizontal portion of the mandible. It is characterised by a more or less marked tendency to lateral deviation of the whole of the mandible of the fractured side, with the result that the dental arches no longer coincide and all functional activity is lost.

This position is maintained even in repose. When the jaws are closed the dental arches are intercrossed, their sole contact-point being in the incisor region. The deviation becomes accentuated when the jaw is

dropped. The deflection of the mandible towards the fractured side produces a similar deformity of the buccal opening, lending to it a very characteristic appearance, rather happily termed *bouche du chantre de village* (village singer's mouth) (figs. 36 and 37).

FIG. 36.—Lateral deviation known as "bouche du chantre de village" (village singer's mouth).

In extreme cases it is almost impossible, even by the exertion of considerable physical force, to reduce temporarily this deviation. In any case such reduction is accompanied by intense pain in the region of the temporo-mandibular joint.

In most cases normal occlusion can be momentarily re-established by the exercise of more or less extreme pressure in the direction contrary to the deviation. But as soon as pressure is removed, the deviation is instantly reproduced by a lateral movement of the

FIG. 37.—Lateral deviation known as "bouche du chantre de village." (The lips are held back to show the position of the dental arches.)

mandible, which the patient declares that he is unable to control.

What is the cause of this malposition? All the patients in whom we have observed it appear to have suffered neglect of their maxillo-facial injuries. In

some instances they never came under special treatment. Their jaws united without mechanical aid, the deviation establishing itself by degrees without attracting particular attention. In others, they had received special treatment, immobilisation mechanisms had been fitted to them and they had then been sent to their homes as convalescents. It is probable that, owing to lack of proper supervision, the vicious attitude develcped during this leave. In spite of very close observation we have not observed the condition to develop in a patient while under our care. This seems to prove that, like the constriction of the myotonic jaw, *la bouche du chantre de village* is a condition which may be guarded against by means of suitable treatment.

At first sight its pathogenesis seems obscure. The deformity of the mandibular arch cannot be regarded as an etiological factor, for we have frequently observed that, in these cases, there was little or no deformity of the mandible and that the normal concordance of the arches was intact. This was proved by taking plaster models of the two arches which, when superimposed, met in perfectly normal occlusion.

Upon further investigation it became evident that the horizontal portion of the mandible had undergone a slight but distinct reduction in length. The distance from the angle to the chin of the sound side was about one cm. longer than that of the fractured side. This reduction had no influence upon the general outline of the mandibular arch. Such reduction is

nearly constant in all united fractures without malocclusion, and we do not believe, therefore, that the slight shortening of the horizontal portion can be regarded as the ultimate cause of the condition.

The same holds good of the articular modifications. In attempting the reduction of the deformity, a varying degree of stiffness of the joint is encountered. This symptom is of varying constancy. In our opinion this is a secondary condition, consequent upon the displacement of the articular surfaces and of the meniscus and their fixation in abnormal position.

It seems to us that the malposition known as *bouche du chantre de village* is not due to bony or articular lesion, but is the outcome of functional derangement of the masticatory muscles. As a result of the fracture, the patient adopts an attitude which he at first corrects spontaneously, and which undoubtedly he could completely overcome were he to practise what neurologists term *l'effort inverse*, or if his will-power were reinforced at the psychological moment by a suitable mechanism. The vicious attitude becomes still further ingrained by muscular phenomena of the dynamic kind, very specific to the condition and characterised by hypertonicity and hyperexcitability of the muscles of the fractured side. These dynamic phenomena appear to withdraw the affected muscles from the influence of the will-power. A sort of disequilibrium results, a lack of co-ordination in the movements of mastication, the muscular synergy having disappeared.

It is for this reason that *bouche du chantre de village* is included in the syndrome which we have termed myotonic constriction of the jaws. This, in its turn, is included in a group of myotonias described by neurologists (Sicard, Babinski)—namely, incurvation of the trunk (camptocormia), *main en bénitier*, *main en col de cygne*, etc.

There is moreover another striking analogy between myotonic constriction and *bouche du chantre de village*. The latter is sometimes seen where no fracture is present, as the result of slight lesions of the cervical region, such as superficial wounds and muscular seton. We have observed a similar etiological peculiarity in the case of myotonic constriction.

Provided that a suitable treatment is instituted at an early stage, the prognosis of this condition is good. Where treatment is deferred for some time after injury, the prognosis is not good. The articular modifications brought about by the malposition are then more difficult of reduction; the muscles undergo structural modification and are less easy to reduce. We have never yet, however, seen an incurable case. Moreover, as in the case of myotonic constriction, we have never observed trophic derangements analogous to those seen in acromyotonia, which so singularly darken the prognosis in this condition.

# CHAPTER V

## MECHANICAL TREATMENT

### I. Elementary Principles

Before entering into the details of the methods advocated in individual cases of mandibular fracture, it is expedient to indicate briefly, for those of our readers who are not specialists, the principal types of apparatus in use in the practice of prosthetic dentistry as well as the results obtainable from each.

These appliances resemble one another in their object, which is to replace teeth which have been lost. They differ from one another in their mode of anchorage. The most simple form may be removed and cleansed by the patient himself; this is termed a *removable* appliance. It consists of a vulcanite or metal plate covering the alveolar ridges or the palate to an extent which varies with the number of teeth to be replaced. The artificial teeth are attached to this plate at the required positions. The retention of this appliance is effected by means of hooks round existing teeth, by sliding posts attached to roots or, where the jaws are totally deprived of teeth, by lateral springs uniting the two artificial rows. Suction

cavities are also employed for upper dentures. These are small cavities on the palatine surface of the plate; by means of suction the patient creates a void, which immediately brings in the factor of atmospheric pressure, by which the plate becomes firmly applied to the roof of the mouth. Rubber washers of different kinds are sometimes employed to reinforce or facilitate the action of these suckers.

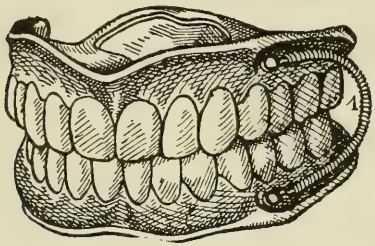


FIG. 38.—Complete set of artificial teeth. Type of removable mechanism. (The stability of this apparatus is assured by the springs on each side, by which the upper and lower dentures are united. On the palatine surface of the upper mechanism a small cavity is shown, known as the sucker. When the mechanism is in place, the patient creates a void by means of a sucking movement which causes the plate to adhere to the palate.)

The prototype of fixed mechanism is the bridge. This is a rigid structure to which the artificial teeth are attached and which requires for its support at least two sound teeth. The teeth which serve as pillars must be strong and healthy. The method of anchorage is by means of metal caps which cover the entire crowns. Where roots are employed as pillars, metal screws are used. These penetrate as far as possible into the root canal, which has previously been enlarged, the free surface of the root being covered by a cap. In addition to these methods of anchorage, which are the ones most in general use, gold screw-blocks, perforated crowns, etc., may be employed. It is not necessary to describe them here.

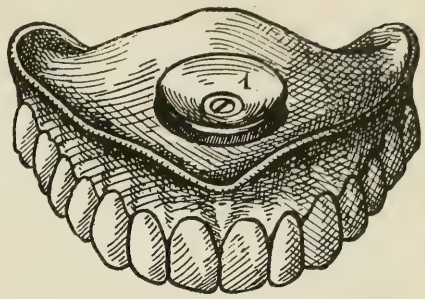



FIG. 39.—Complete appliance for the upper jaw with india-rubber sucker. (To reinforce the action of the sucker as described in fig. 38 a small india-rubber washer (1) is employed. It adheres to the palate in the manner of a cupping-glass.)

The platform of the bridge is composed of metal, and sufficient space is left between its lower surface and the gum to permit of the bridge being cleansed *in situ*. The apparatus is permanently attached to its anchorage by an osteoplastic cement. Of all mechanisms the bridge is the one which permits of the most perfect restoration of function. The pillars, however, must be very judiciously chosen and prepared, and it is essential that disproportionate demands should not be made upon them. For this reason, small bridges carrying not more than three teeth are the most satisfactory.

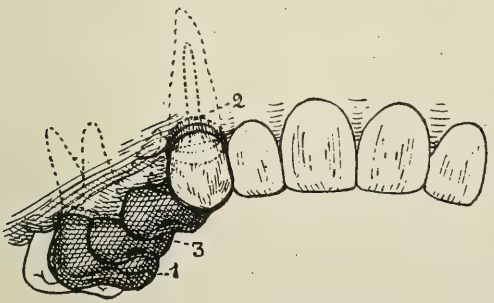



FIG. 40.—Bridge. Type of fixed apparatus. (The first molar is covered by a metal cap (1); the root of the canine serves as support for a screw-cap (2). These two points act as pillars. Between them stretches the platform of the bridge, represented in the drawing by two solid crowns which replace the absent premolars (3). Between the platform of the bridge and the gum a sufficient interval is allowed to permit of the cleansing of the mechanism.)

There is yet another type of mechanism

which combines the methods of anchorage of the bridge with those of the plate, and this is termed the removable bridge. It is a mechanism designed by us for the treatment of median pseudo-arthrosis. It is described in full detail in a later chapter, and to that we refer the reader.

The description of these three types of apparatus shows the extent to which teeth which have been retained may be employed. The principles are well known to stomatologists; they serve as valuable guides in the manufacture of the numerous mechanisms employed in the treatment of fracture of the jaw.

Another important physiological phenomenon, and one which should not be lost sight of, is the extreme mobility of the temporo-mandibular joints and their wonderful capacity for adaptation. Examples are constantly furnished by modern dentistry and orthodontics.

## II. The Immediate Treatment of Lesions

What methods should be employed immediately after injury in mandibular fracture?

The large majority of cases might undoubtedly be immediately transferred to special centres at the base for the treatment of maxillo-facial injury. These comprise the less serious lesions, the incomplete fractures, and the complete fractures with little or no loss of substance. Such cases have all passed through a field station. The wounds of exit and of entry have been dressed and drainage of the integumental side,

where necessary, has been effected. At the evacuation hospitals where there is usually provision for stomatological treatment, the preliminary treatment just referred to can be supplemented by thorough cleansing of the buccal cavity, and by the application of a four-tailed bandage or suitable sling to give temporary rest to the fragments. In lieu of the four-tailed bandage an Angle's arch may when possible be adjusted. This mechanism provides an excellent means of obtaining an emergency immobilisation. It is a kind of general appliance which may be adapted to each particular case, and every evacuation hospital should be well provided with it. To the practised stomatologist its attachment requires half an hour at the most, and the slight fatigue experienced by the patient after the manipulation is completed is amply compensated for by the comfort experienced during the rest of the journey. Such cases arrive at the base in excellent condition. Their diagnosis papers should be marked "evacuation at a centre for facio-maxillary treatment," which greatly facilitates their distribution among the hospitals of the interior.

All cases in which the lesion is at all grave should be kept for a time at the front. It is in these cases, which are too varied and complex for description here, that complications are most likely to arise. Such are: primary and secondary hæmorrhage of the lingual, facial, external carotid, and internal maxillary and its branches; traumatic shock; asphyxia from division of the genio-glossal muscles and consequent

descent of the tongue into the pharynx; primary infective conditions; and secondary broncho-pulmonary, gastro-intestinal, and general infective conditions.

We do not propose to enter into the details of either a stimulant medication or its indications.

By surgical drainage of the tract, in accordance with the methods of general surgery, it is possible not only to reduce the local infective conditions, but to discover and to ligature arteries which have been laid bare and which are liable to prove a source of secondary hæmorrhage.

Early resection of the bone should be avoided. Free splinters should be removed, as well as bony fragments, portions of teeth, and projectiles situated in the soft parts. In order to prevent incessant flow of saliva and to facilitate feeding, it is sometimes necessary to perform emergency operations of a plastic nature upon the teeth and lips. This is a resource, however, which should be employed with great discretion and under conditions only which permit of the efficient drainage of the wound.

To guard against asphyxiation, a silk thread should be passed through the tip of the tongue and attached to the dressing by means of an adhesive strap. This method allows the tongue to be drawn forward and kept in position. The performance of trachæotomy cannot be too strongly condemned. Not only is it entirely useless in the circumstances, but it is extremely dangerous, for it creates a port of entry in the near

proximity of an extremely septic area from which infection is very liable to spread.

The stomatologist on his side should see that the buccal cavity is kept scrupulously clean. Only absolutely necessary extractions should be made, however, for it is essential that the state of shock should not be augmented. Temporary treatment should be confined to making the patient comfortable. Sedative dressings should be applied to the surfaces of teeth which have been broken, exposing the dental pulp. The fragments of bone should be immobilised by means of mechanisms which are easy of adjustment. Angle's arch (fig. 49), interdental and intermaxillary ligature are the measures recommended (fig. 41).

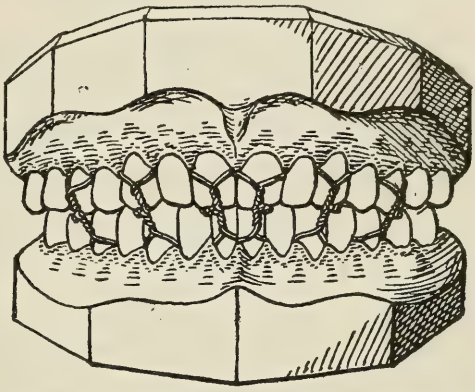


FIG. 41.—Extemporary method of obtaining immobilisation in occlusion. (Ligatures of brass wire are slipped round the necks of a certain number of corresponding teeth of both jaws. The ends are then interunited, the result being a perfect immobilisation of the mandibular fragments.)

On the recommendation of Pont a simple pocket-case of instruments has been adopted by the medical service, which renders the adjustment of Angle's arch a very simple manœuvre ; one, moreover, which may be employed at a stationary ambulance or at an evacua-

tion hospital. This pocket-case contains three Angle's arches, a pair of flat pliers, a pair of scissors, a file, and a wrench.

It is most important that profuse irrigation by a douche be carried out three or four times a day. Permanganate 1 in 8,000 and nitrate of silver 1 in 20,000 are the best solutions.

It is a wise precaution to feed these patients by a naso-pharyngeal tube. In this class of case, movements of deglutition are invariably both painful and awkward.

Sébileau states that patients have come under his notice upon whom gastrostomy had been performed. This operation is never indicated except where the simple apparatus necessary for œsophageal catheterism is lacking.

### III. Mechanical Treatment of Fractures

The management of mandibular fracture involves two problems: to obtain a good union on the one hand and, on the other, to maintain or to restore the occlusion, for this is essential to good mastication.

In a case of simple contact fracture without loss of substance, this double object is readily fulfilled. Where there is loss of substance the problem is a more delicate one. How is a good union with satisfactory callus to be effected when the fragments are separated by an interval of varying extent? On the other hand, admitting the possibility of effecting a union, how is function to be preserved?

Certain surgeons, in pursuance of the principle advocated formerly by Claude Martin, make their objective the re-establishment of the occlusion of the teeth. Their method consists, whatever the extent of the breach, in immobilising the mandibular fragments in such a way that the inferior teeth preserve their articulation with those above them. Martinier and Lemerle, in a work which appeared in 1915, describe the method as follows :

" After a loss of substance sufficient to produce shortening of the mandible, the fragments should be regularised and the case should be handled as in partial resection of the bone. A block of vulcanised india-rubber inserted into the wound prevents cicatricial retraction. When the epidermal covering of the scar is complete, the block is replaced by an ordinary mobile dental apparatus the base of which, by filling the cavity formerly occupied by the lost fragment of bone, assures the continuity of the mandible."

The method of treatment by the immediate employment of mechanical contrivances could not be better described, nor could its advocates more clearly demonstrate their attachment to the principles advocated by Claude Martin.

It is not possible for us to identify ourselves with these views. The regularisation of the fractured surfaces and the removal of splinters, some of which may have retained their periosteum and thus their

[1] Martinier and Lemerle, *Prothèse restauratrice buccofaciale*, J. B. Baillière, 1915.

vitality, appears to us contrary to sound surgical principles. Further, how will the patient bear the immediate application of a mechanism, which is bound to retard the cicatrisation of the wound and which must induce septic conditions of the buccal cavity, exposing him over a long period of time to the dangers of broncho-pulmonary, gastro-intestinal, or general infection ?

Even more deplorable in our view is the result aimed at, for all that the method can hope to achieve is a pseudo-arthrosis. We know that eventual mechanical treatment is able to effect a certain solidarity between the mandibular fragments and to re-establish, to a certain extent, the masticatory function. But one cannot fail to recognise that the result is a transitory one, the period of usefulness of such mechanisms being dependent upon the preservation of the teeth. The latter, serving as they do as points of anchorage, undergo a supplementary strain which is not calculated to prolong their duration, and irremediable infirmity must sooner or later show itself.

It does not seem that Martinier and Lemerle's technique has been very frequently employed. On the other hand, we know that the re-establishment of normal dental occlusion forms the chief aim of many stomatologists, who are content to immobilise a fractured mandible in good occlusion without troubling about the co-adaptation of the bony fragments.

Where the loss of bony substance is small, the method has much to recommend it, for union under such

conditions almost invariably follows its employment. Even in cases where the loss of bony substance is considerable, namely, 2–3 centimetres, the fragments have been known to unite as the result of simple immobilisation. Whether in these cases some shreds of periosteum remained intact, or whether destruction was not as extensive as it appeared to be, is not known. In spite of these results, it is none the less true that in this class of case, treated in this manner, union is exceptional and can never be safely predicted.

The methods which we ourselves advocate have for their chief object the prevention of pseudo-arthrosis. As will be shown later, the object is usually to establish the co-adaptation of the fragments, even at the price of mandibular deformity. It is not essential that the mandible should reacquire its anatomical outline for a satisfactory occlusion with restoration of function to be established. As we have shown in another place [1] it is always possible to correct or to compensate for the deformity.

Restorative mechanisms are employed only to remedy very extensive pseudo-arthroses, and then only when surgical measures have failed.

. . . . .

In view of the conditions peculiar to mandibular fracture and the complex problems associated with

[1] Imbert and Réal, "Les fractures latérales de la mâchoire inférieure avec perte de substance," *Odontologie*, September 30th, 1916.

its treatment, certain authors have found it expedient to treat these lesions on special therapeutic lines.

Cavalié proposes "a general anatomical clinical treatment divided into three periods."

*First period.*—Restoration of the mandibular arch either by surgical means, by mechanism, or by the simultaneous employment of both methods.

*Second period.*—Orientation of the arch by surgical or mechanical means or by both.

*Third period.*—Temporary and permanent adjustment of mechanical appliances.

Frey [1] describes four stages in the treatment of mandibular fracture. The first stage, that of orthognathia, has for its object the re-establishment of the normal relationships between the teeth and the jaw. The second stage, that of contention, consists in the maintenance of the fragments in the conditions of normal intermaxillary and interdental relationship which have already been established. The third stage comprises dynamic exercises, the stomatologist endeavouring to re-establish the synergy of the masticatory muscles and to overcome the retraction of the cicatrices. The fourth stage is that of mechanical replacement or prosthesis (from the Greek, *I replace*).

The physiological method advocated by G. Villain [2] does not, as a matter of fact, introduce a fresh thera-

[1] Frey, "Un aperçu de la prothèse restauratrice dans les fractures des mâchoires et mutilations de la face," *Paris médical*, August 21st, 1915.

[2] Geo. Villain, "Traitement physiologique des fractures et des luxations du maxillaire inférieur," *Odontologie*, July and August, 1916.

peutic idea. This author advises, and very justly, the systematic employment of the movements and of the tonicity of the muscles as forces of reduction and contention. In this connection he advocates the crank, an excellent apparatus to which we shall return later.

From our point of view all these authors possess the same fault, namely, that of making the restoration of dental occlusion their primary object, union of the fragments being given a secondary place. Moreover, surgeons who have been disappointed in the results of special technical methods are not likely to accept willingly yet another special therapy and a fresh terminology. For this reason we shall continue to employ the terms "reduction" and "contention," the significance of which is well known and their employment in connection with general surgery universal. By "reduction" we mean, not only the co-adaptation of the fragments with the object of effecting a satisfactory union, but also the establishment of an occlusion which will permit of satisfactory mastication. It is only in extreme cases accompanied by considerable loss of substance, where it is impossible to bring the fractured surfaces together, that "reduction" is confined to the re-establishment of normal dental articulation.

In recent fractures, that is to say, those in which the processes of bony repair are not far advanced, early reduction is readily obtainable. Treatment is confined to the employment of an immobilisation

apparatus, constructed by special methods upon a model of the jaw modified by the form which it is desired to produce.

In old fractures rapid correction of the deviations and deformities of the mandible is not possible. These cases necessitate the employment of mechanisms the action of which is more or less gradual, and which are not replaced by passive appliances for contention until the jaws have recovered their normal relationship. The statement of this general principle is necessary to a complete understanding of the following chapter, in which the methods of reduction and retention to be employed in each type of fracture are described.

The mechanisms described are either those which we ourselves most commonly employ, or those which in the hands of others have given the most satisfactory results. It may seem a little surprising that no mention is made of earlier mechanisms, especially those with extra-buccal attachment employed by Claude Martin, Kingsley, Richet, etc. As a matter of fact, these have practically disappeared from modern maxillo-facial practice. Those of our readers who desire further information concerning them should consult Martinier and Lemerle's book on the subject, to which reference has already been made.

Before passing to a detailed account of our own methods, it is expedient to give the therapeutic classification formulated by Sauvez, the scheme of which is very sound and which we have very largely adopted.

## Table of Treatment in Mandibular Fracture

### FIRST CLASS

Each fragment contains teeth (median or paramedian fracture)

#### First Division

Without loss of substance

| | |
|---|---|
| *Case* 1: No displacement. | Mechanical treatment. Jaws not ligatured together. |
| *Case* 2: Displacement. | Mechanical treatment. Jaws not ligatured together. |

#### Second Division

With loss of substance

| | |
|---|---|
| *Case* 1: Loss slight. Union of fragments effects a tolerable occlusion. | Mechanical treatment. Jaws not ligatured together. |
| *Case* 2: Loss comparatively large. Union does not effect occlusion, but this may be done by means of a fixed bridge in one or three parts. | Mechanical treatment. Jaws not ligatured together. |
| *Case* 3: Loss very extensive. It is impossible to employ a fixed bridge. | 1st. Mechanical treatment. Jaws not ligatured together.<br>2nd. Mechanical treatment. Jaws not ligatured together.<br>3rd. Surgical treatment. Jaws ligatured together. |

### SECOND CLASS

One fragment is toothless (retrodental fracture and fracture of the ramus)

#### First Division

Without loss of substance

| | |
|---|---|
| *Case* 1: No displacement. | Mechanical treatment. Jaws ligatured together. |
| *Case* 2: Displacement. | Combined surgical and mechanical treatment (plate). Jaws ligatured together. |

SECOND DIVISION

With loss of substance

| | |
|---|---|
| *Case* 1: Slight loss. Union effects a tolerable occlusion. | Treatment either surgical or mechanical (plate). Jaws ligatured together. |
| *Case* 2: Extensive loss. Union is either impossible, or, if effected, would not bring about occlusion. | Surgical treatment. Jaw ligatured together.<br>Mechanical treatment, temporary or permanent. Jaws not ligatured together. |

**Preparatory Treatment.**—No decision in regard to treatment should be made until a good skiagram of the lesion has been obtained, not only in order to facilitate diagnosis but in order to ascertain the condition of the site of the fracture. It is also absolutely essential that the mouth be carefully prepared before instituting a mechanical therapy.

After the buccal cavity has been minutely cleansed and infected roots have been extracted, the fracture site should be examined with particular care. Fragments of roots of teeth are sometimes present, and these considerably retard union. Some very striking cases of this kind have passed through our hands. Roots included in the region of the fracture are well shown by skiagrams. They are those of teeth adjoining the fracture site, and they appear to plunge down into it. Not only should remains of roots be extracted, but also teeth the denuded roots of which might convey to the site of fracture infection from the buccal area.

Patients frequently come in who are in an emaciated and weakened condition; the way in which they

respond to general treatment is very striking. Our method is to give two Ferrier's cachets [1] a day, to which fifteen drops of adrenalin solution, 1 in 1,000, are added (Sergent, *Presse médicale*, 1913, No. 93).

This recalcifiant (*médication récalcifiante*) treatment is pursued for ten days at a time, with intervals of ten days.

The general condition improves very rapidly under this treatment, which has, presumably, a definite action in promoting the growth of the callus. The work of P. Carnot and C.-L. Slavu (*C. R. de la Société de Biologie*, 1900, vol. lxviii. p. 832) upon the influence of adrenaline upon bony repair and the growth of the callus is interesting in this connection. These authors are entirely in favour of the method.

Care must be taken during the entire period of treatment to keep the mouth in a state of absolute cleanliness. Every patient should clean his teeth with soap at least twice a day. Irrigation by means of a douche should be performed as frequently as the condition of the lesions demands. Permanganate 1 in 8,000, and nitrate of silver 1 in 20,000, are the best solutions for this purpose.

The problem of feeding is solved in the following manner. Those patients whose jaws are not immobilised, as well as those whose jaws are kept closed,

[1] Ferrier's cachets:

| | |
|---|---|
| Precipitated calcium phosphate | 0·50 centigr. |
| Calcium carbonate | 0·30 ,, |
| Sodium chloride | 0·15 ,, |
| Calcined magnesia | 0·10 ,, |

are given a liquid or semi-liquid diet consisting of minced meat, vegetable *puree*, prepared foods, thick soups, milky foods, and eggs. Neither at the Hôtel Dieu, Marseilles, nor at the Hospice de Sainte Marguerite, where we had the care of 200 to 250 patients, have we ever had any difficulty with this diet. Patients do very well on it. In certain severe cases, which came to the hospital in a very debilitated condition, the increase of weight, namely 8½ lbs. in fourteen days, was really remarkable. The Ferrier cachets were of course administered simultaneously.

As soon as patients are fitted with their retention mechanisms they are usually able to eat the hospital diet.

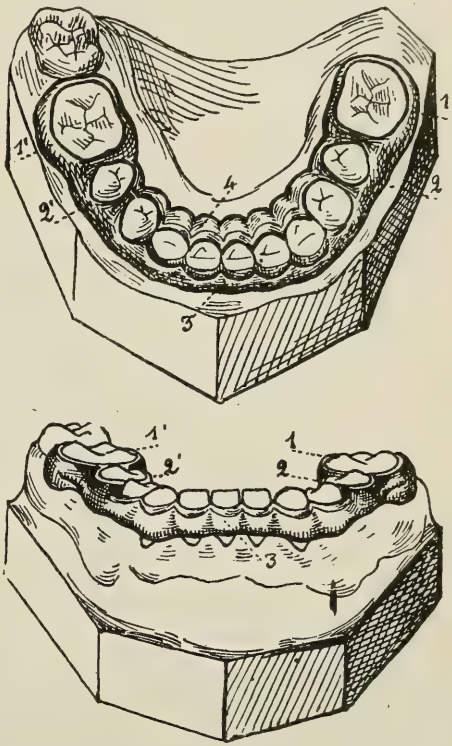
*A.* **Anterior group: Median and Paramedian Fracture.**—The deformities characteristic of these fractures have already been described.

The therapeutic indications vary in accordance with the amount of substance lost. It may be small, 1 to 1½ cm.; medium, 1½ to 3 cm.; or large, 3½ cm. and over. The extent of the loss is revealed by the degree of deformity and by skiagrams.

1. **Recent Anterior Fracture.**—(*a*) *Slight loss of substance* (up to 1½ cm.). The method here is, first to restore the mandible to its original form and then to immobilise, the procedure being as follows:

A good model of the jaws is made, preferably in plaster. The model of the lower jaw is sawn in two along the line of fracture. Each portion is then brought into normal occlusion with the teeth of the upper

jaw. To a stomatologist the task is an easy one. Normal occlusion being established, the two portions of the lower jaw are fixed in position by means of plaster. The model of the mandible as it was before




FIGS. 42 and 43.—Double splint with anchor bands for the immobilisation of median or paramedian fracture with slight loss of substance. (1, 2, 1′, 2′, are four German silver bands, accurately adapted and attached to the crowns by cement. They form a solid anchorage for the anterior and posterior splints, 3 and 4, which are soldered to them. These splints are of cast silver, and cover only about a third of the crowns, leaving the triturating surfaces and the necks free. The apparatus may be rendered removable by replacing the soldered anchor bands with bands fastened with a screw and nut. See figs. 50 and 51.)

injury is thus obtained, and the mechanism for immobilisation is constructed on the model.

The method which we recommend is the double splint with anchor bands shown in figs. 42 and 43.

The absolute immobility conferred by this mechanism is due not only to the method of anchorage but also to the splints themselves which, where requisite, may be ligatured to the teeth.

The anterior and posterior splints only partially cover the crowns of the teeth, the upper and lower thirds remaining free, thus facilitating both cleansing and control. The splints are easily removed either by cutting the bands or by unsealing the cement.

This mechanism is infinitely superior to the type of cast silver splint shown in fig. 44, which has the drawback of covering practically the whole of the crowns as well as a portion of the muco-periosteum.

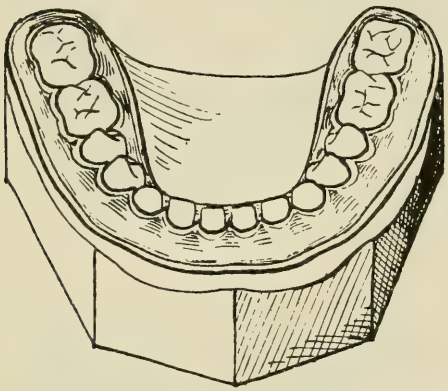


FIG. 44.—Open splint of cast silver for the immobilisation of median or paramedian fracture. This cap splint leaves the occluding surfaces of the teeth free.

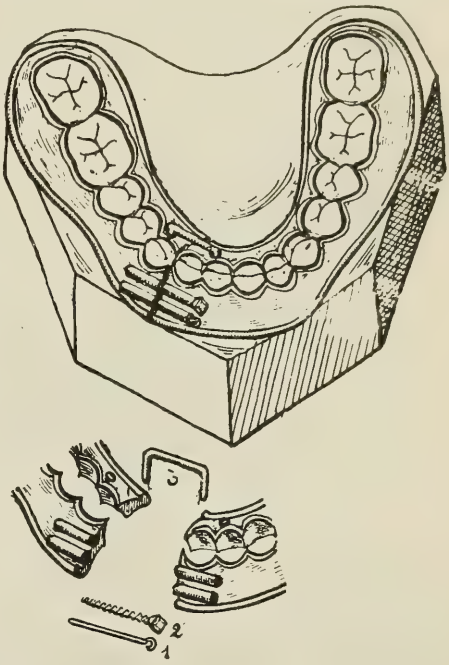
The cap splint in two pieces is a mechanism designed to facilitate supervision of the fracture without the necessity of removing the mechanism. The two pieces are separated and united at will by means of a special contrivance. The mechanism shown in fig. 45 is a perfect expression of this principle. It is described by Dr. Sauvez and constitutes a very happy modification of the open splint.

Double splints in cast metal, attached posteriorly by means of a hinge and connected at intervals by screw-bolts, may also be used for the purpose.

Figs. 53, 54, and 55 show a mechanism designed to effect this method of anchorage. The principle is that

of adjustable bands, a common technical device in dental surgery and one that has been imported into the therapeutics of mandibular fracture. It is unnecessary to enter here into the details of its construction.

The soldered bands shown in fig. 42 may be replaced by adjustable bands similar to those described on a later page in connection with Angle's arch. This method of anchorage renders the splint removable.




FIGS. 45 and 46.—Metal splint in two pieces. (This splint is sawn in two at the fracture site. The two portions are firmly united by means of bolts. The two anterior bolts, 1 and 2, of which one is threaded to form a screw, prevent vertical displacement. The posterior U-shaped bolt prevents horizontal separation of the fragments. The mechanism is designed by Dr. Sauvez.)

(*b*) *Medium loss of substance* (1½ cm.).—In this class of case compensatory contraction must be allowed for and union is more favourable if the fragments are not immobilised in their position of normal occlusion. The model on which the immobilisation apparatus is constructed should not therefore exactly conform to the normal shape of the jaw, but it should to a certain extent

reproduce the deformity characteristic of the fracture. It should, however, correct the tilting inwards of the occlusal surfaces of the molars, which is sometimes very marked.

An immobilisation apparatus constructed upon such

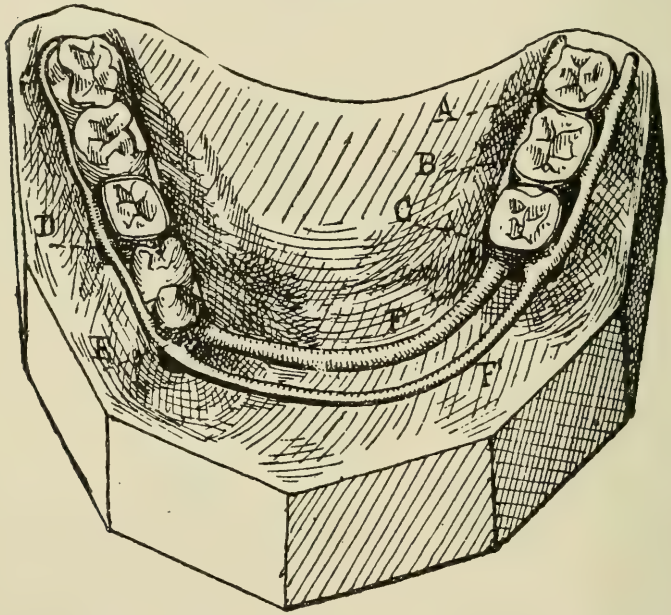



FIG. 47.—Immobilisation of median fracture with large loss of substance. (Anchor bands are cemented to the molars A, B, C, D, E. They are soldered together and rendered stable by two rigid rods F F′, thus assuring the immobilisation of the fragments and maintaining them in their normal position.)

a model will result in union with slight contraction. The contraction is readily remedied by various orthodontic measures for obtaining mandibular expansion.

Correction of the contraction should not be deferred until after ossification of the callus. *It should be undertaken at the moment when the mobility of the frag-*

*ments appears to be arrested by the resistance of the callus, while skiagrams show that ossification is not as yet very far advanced.* Intervention at this moment is attended by results which are positively astounding.

Some years ago Monod published an account of a

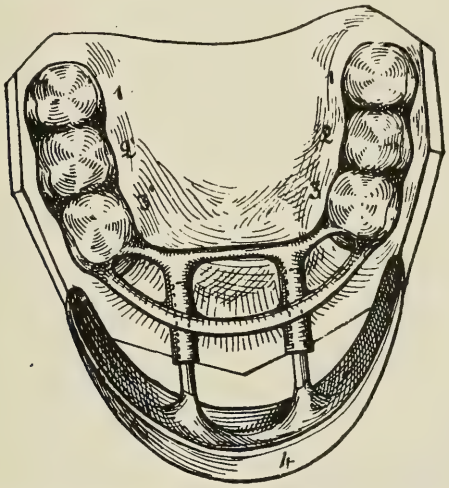



FIG. 48.—Apparatus for the immobilisation of median fracture with large loss of substance. (The lateral fragments are extremely mobile, which necessitates a very firm method of anchorage. The anchor bands are replaced by crowns (1, 2, 3, 1′, 2′, 3′) which are soldered together. The interior surfaces of these crowns are furnished with studs or screws which penetrate the pulp cavities or even the posterior roots. The anchor blocks are united by two transverse bars. The vulcanite piece (4) serves as guide for cheiloplastic operation. It is attached to the principal mechanism by two parallel rods running in two tubes. After cheiloplastic intervention this apparatus may be used as an extensor for the lip.)

case which is very significant in this connection. He effected extension of the callus with the object of reducing a marked contraction of the jaw. The ultimate union was in no way impeded; in fact, it almost seemed as if the extension of the callus had exercised a stimulating effect upon the osteo-genetic processes.

More recently, at the Interallied Dental Congress, Caumartin and Valadier described cases of prolongation of the callus with perfect union. The mechanism which we ourselves employ for this purpose is shown in fig. 52 and will be described later.

It is easy to compensate for slight contraction by the method known as "jumping the bite." This is a manipulation practised by many stomatologists and is carried out by means of a variety of mechanisms into the details of which it is not necessary to enter here.

(*c*) *Large loss of substance* (3 cm. and over).—The breach is here too large to be compensated for by the union of the fragments. All that can be done is to maintain the fragments in normal position until after the cicatrisation period (figs. 47 and 48). Later they are united by a bony graft, or by a restorative mechanism in the manner of Claude Martin.

2. **Old Anterior Fracture.**—For the correction of deviations which it is impossible to reduce, we usually employ Angle's alignment wire, a very common appliance in orthodontics.

Angle's apparatus consists of :

1. A German silver alignment wire with threaded ends fitted with nuts.

2. Two anchor bands of the same metal, to the buccal surface of which tubes are attached, into which the extremities of the alignment wire are slipped.

*Application of the Mechanism.*—The anchor bands are attached to the first, or, if these are missing, the second molars. The arch is placed in front of the

teeth in such a way that the anterior curve is in contact with the incisors. All the teeth in contact with the wire arch are then attached to it by ligatures, which are passed through the interdental spaces and tied. The alignment wire should not be fitted to the

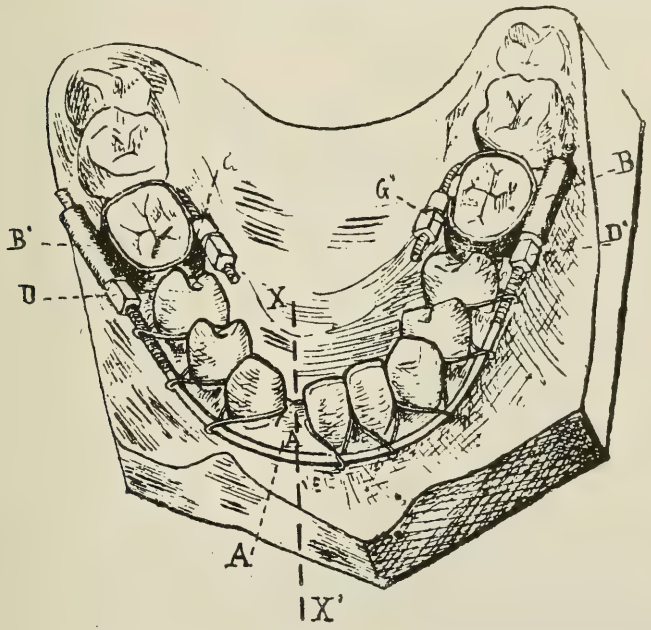
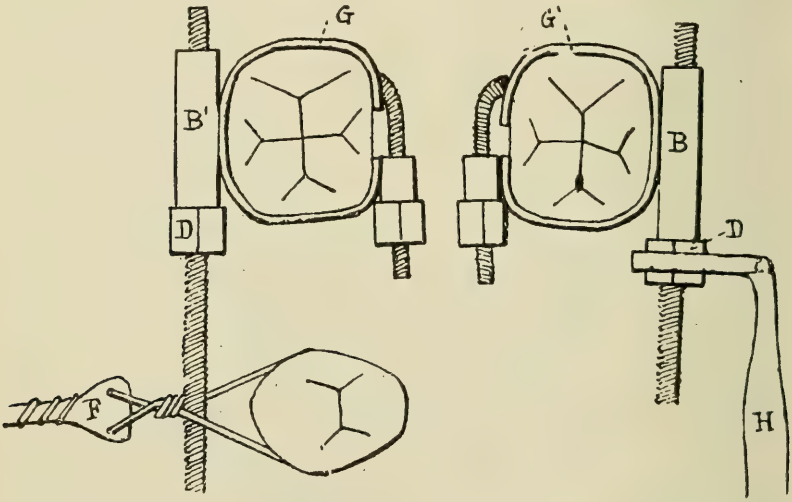



FIG. 49.—Angle's apparatus for paramedian fracture. (The line *X X'* represents the fracture site. The apparatus consists of a German silver arch *A*, running in two tubes *B B'*, attached to two screw bands *G G'*. The anchor bands are attached to the first molars. All the teeth in contact with the alignment wire are attached to it by brass wire ligatures passed through the interdental spaces. The extremities of the alignment wire are threaded and furnished with screws placed at the anterior extremities of the tubes.)

lingual surfaces of the teeth. It should be given a parabolic form, which is the ideal mandibular outline, and to which the amended jaw will conform.

The method of action is briefly as follows: In the

first place, the elasticity of the metal tends to straighten out the dental arch and thus to separate the two fragments to which it is attached. In the second, by tightening the brass wire ligaments attached to the teeth implanted in the fragments, it is possible gradually to draw the latter towards the alignment




FIGS. 50 and 51.—Details of the extremities of Angle's arch. (*D D'* nuts; *B B'* tubes containing the extremities of the arch. Fig. 50 shows the method of applying the brass wire ligatures. Fig. 51 shows the manner of tightening the nut by means of the special screw-key.)

wire, thus restoring the normal dental alignment. Finally, by tightening the nuts against the anterior extremities of the tubes, the diameter of the alignment wire is increased and it is forced in consequence to expand transversely (fig. 49).

The alignment wire is an excellent mechanism in this condition, where it is a question of mobilising two fragments of approximately the same size, subjected

to muscular influences which are approximately equal, and which produce convergent symmetrical displacement.

The principle of the method is the interaction of forces, the one fragment serving as a fulcrum for the mobilisation of the other and vice versa. Where, however, there is marked discrepancy in the size of the fragments, the smaller inevitably tends to become displaced.

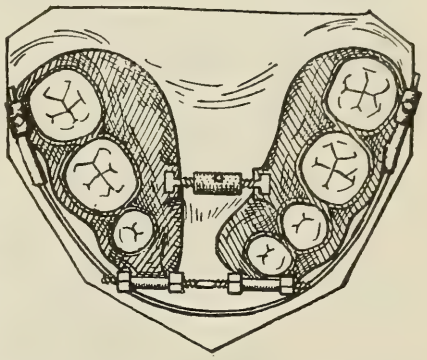
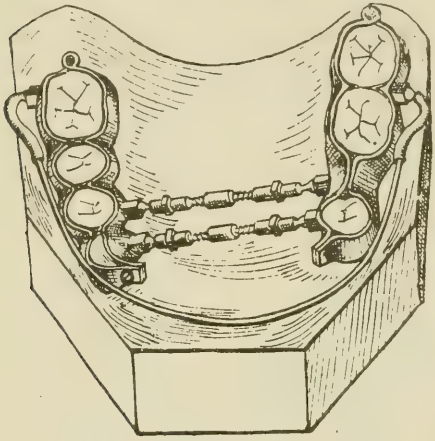


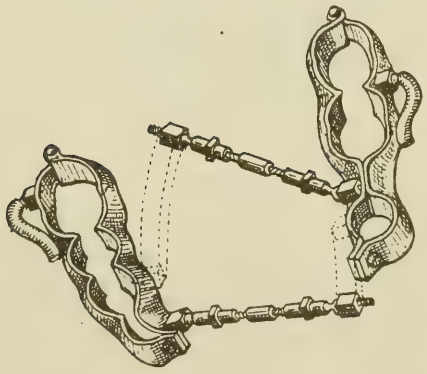
FIG. 52.—Apparatus for expansion of the mandible. (Each lateral fragment is enclosed in a splint carefully cemented to the teeth, the base of which descends as low as possible along the entire length of the lingual surface. The posterior jack-screw is placed very low, approximately in the region of the apex. Its two extremities are contained in two cavities in pigeon's-nest form on the lingual face of the splints, where they are secured by means of a pin. A second extension mechanism acts upon the anterior extremities of the fragments. It is fixed as close as possible to the occluding surfaces of the teeth. It consists of a threaded rod running in two tubes which are attached to the anterior extremities of the splints. The screw-rod is furnished with four nuts placed one at each entry and one at each exit of the tubes. By manipulating these screws, expansion and immobilisation may be effected at the same time.)

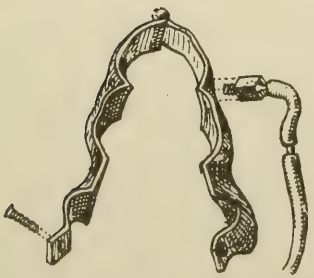
Where greater force is required to overcome the mandibular contraction, the mechanism shown in figs. 52 and 53 is preferable. Here the expansive force is conveyed by means of jack-screws.

In this instance the stress is directly transmitted to the mandibular fragments, owing to the fact that

FIGS. 53, 54, and 55.—Extension apparatus for use in mandibular contraction. (This apparatus is described by Dr. Besson, and possesses the following characteristics—in many particulars it closely resembles an apparatus seen by us at Val-de-Grâce, where it was employed by Dr. Frey: "It consists of two metal cap splints struck in two parts, articulated at the back by means of a hinge and closed in front by means of a screw. The two splints are accurately applied to the fragments, covering the lateral faces of the teeth and the gingival mucosa as far down as possible. They are cemented to the teeth, the occluding surfaces of which are left free. Between the two splints in front two jack-screws are fixed, one above, the other below. The first is placed as close to the teeth as possible. The second is placed as low down as possible between the mesial surfaces of the same teeth. Upon the lingual surface of the splints, as low down as possible, and behind the teeth which erupt at six years, attachments are fixed for an elastic arch of piano wire which surrounds the inferior dental arch. The attachment of the jack-screws and the vestibular arch is effected by means of knee-joints. This gives an extreme pliability to the entire mechanism. It also facilitates the individual movement of each fragment in response to the forces acting upon it." The extension apparatus shown in fig. 52, which immobilises the fragments while at the same time holding them apart, is chiefly indicated in fracture where union may be anticipated, and which are better for being kept immobilised during the extension period. Besson's mechanism, on the other hand, owing to its extreme pliability, is more suitable for employment in confirmed pseudo-arthrosis.)







the jack-screw is placed very low, very nearly at the point of union of the alveolar and basilar portions of the mandible.

In cases where it is not possible to employ the sub-lingual jack-screw, Duchange's apparatus is indicated. Ingenious appliances with extra-buccal anchorage have been introduced by Guérini of Naples.

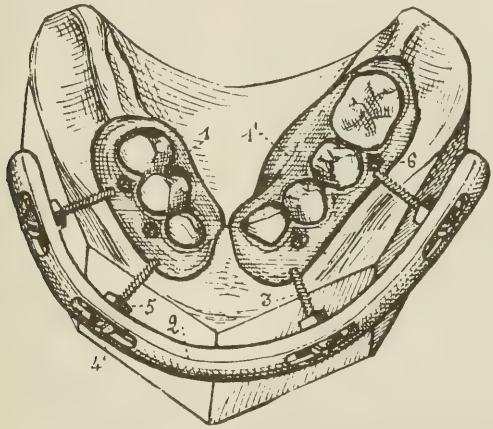



FIG. 56.—Duchange's apparatus for the correction of mandibular contraction. (Each of the two fragments is fitted with a cap splint (1, 1') which is cemented to the teeth; anchorage is reinforced by screws (6) penetrating the interdental spaces. Threaded rods (3) are soldered to the metal caps. The free ends of these rods are passed through eyelet holes arranged at intervals in a rigid metal arch (2). By turning the nut (5) and the counter-screw (4) in the threaded rod, the mandibular fragments are drawn into the required position.

When the mandibular deformity has been corrected, the fragments are immobilised by either retention mechanisms or by the double splint with anchor-bands shown in figs. 42 and 43.

3. **Double Fracture.**—Similar methods are employed in the reduction of bilateral fracture with median third fragment. Fig. 57 shows such a fracture,

and the instrument for its reduction is shown in figs. 42 and 43.

Occasionally the median fragment shows a tendency to downward and outward displacement, a condition which it is difficult to correct by means of Angle's alignment wire. In cases of this nature intermaxillary anchorage is employed. A mechanism furnished with hooks is attached to the third fragment by means of anchor-bands. The hooks are connected, by means of elastics with a similar device attached to the anterior teeth of the upper jaw.

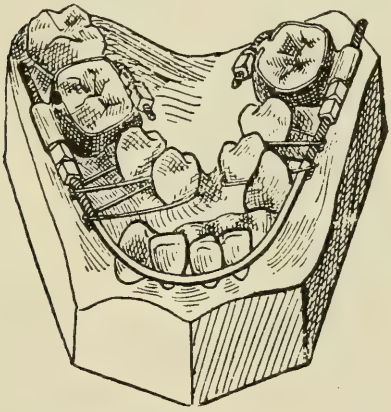


FIG. 57.—Angle's arch employed to reduce bilateral fracture. The jaw is the same as that shown in figs. 42 and 43, where the fracture is reduced and immobilised by a double splint with anchor bands.

Median and paramedian fracture is sometimes complicated by vertical displacement of the fragments. This produces an irregularity in the horizontal plane which must be corrected before immobilisation. This is best done by means of an apparatus similar to that represented in fig. 59. It is composed of cap splints cemented to the lateral fragments. A firm anchorage is essential, and this is assured by screws at the interdental spaces. A spring is attached to the lingual aspect, the action of which is slightly to separate the

two fragments and to lower the elevated fragment. Attached to the labial surfaces are two pierced metal projections. When reduction is complete these exactly face one another. All that remains to be done is to immobilise the fragments by introducing a U-shaped bolt into the holes in the splint previously occupied by the spring, and a straight threaded bolt furnished with nuts into the holes in the metal projections.

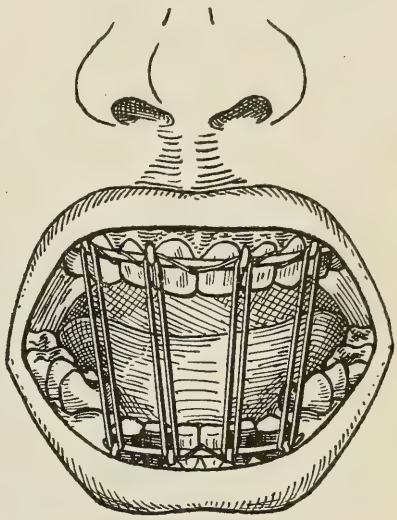


FIG. 58.—Method of intermaxillary anchorage for the purpose of bringing a median fragment displaced downwards and forwards into occlusion. The teeth of the upper jaw are fitted with a rigid metal rod to which hooks are attached. A similar device is attached to the teeth of the loose fragment. Elastic bands of varying number are stretched between the hooks of the two arches, thus correcting the deviation.

Should the vertical displacement not yield to this method, a mechanism with intermaxillary anchorage, such as that shown in fig. 64, should be employed.

In this case elastic bands are stretched between each of the fragments and the upper jaw. Their action tends to separate the fragments and to draw them into contact with the superior dental arch until normal occlusion, that is to say reduction, is obtained.

It was in cases of this sort that, in former days, Cl. and Fr. Martin practised their "open mouth" treatment.

We have frequently been struck by the facility with which considerable loss of substance in the mental region is made good. The characteristic is quite

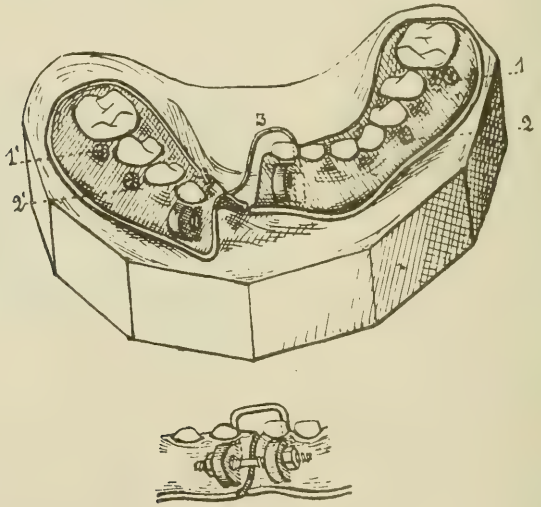



FIG. 59.—Apparatus for the correction of vertical deviation in median or paramedian fracture. The metal splint is divided at the fracture site. Each portion is cemented to the teeth and is also secured by means of screws (1, 2, 1′, 2′) between the interdental spaces. A spring (3) corrects the deviation. When the reduction is effected the fracture is immobilised by means of bolts which fix the two splints in position.

specific and is not observed in lateral fracture. It may be due to the richer vascularisation of the mental region.

*B.* **Posterior Fracture.**—Of all classes of fracture, this is the one most liable to terminate in pseudo-arthrosis. Every effort should be made to bring the

fragments into apposition, in the hope of effecting a union.

1. **Recent Lateral Fracture,** with slight or medium loss of substance (up to 3 cm.).—(*a*) *Posterior fragment containing teeth or roots suitable for purposes of anchorage.*

When the loss of bony substance does not exceed 1½ cm., treatment consists in immobilisation of the

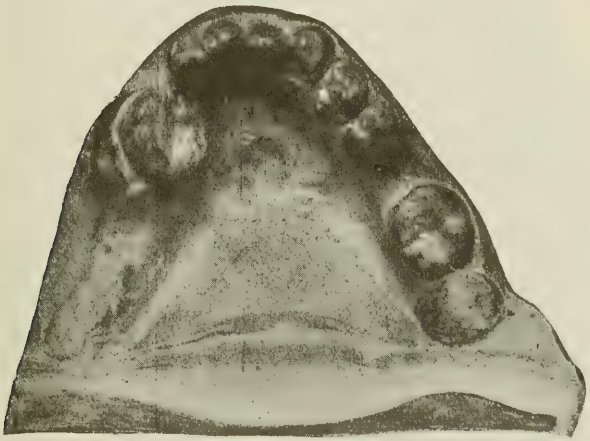


FIG. 60.—Lateral fracture with large loss of substance. Spontaneous union. Compensatory displacement of the posterior fragment.

fragments in normal occlusion by means of either a double splint with anchor bands or a bridge. In the case of the latter it is advisable to strengthen the anchorage of the supporting crowns by screws or bolts penetrating well into the pulp-cavities and canals, the latter having been previously enlarged.

Where the loss of substance is greater (up to about 3 cm.), simple immobilisation should also be employed, provided always that the destruction is not absolute,

and that splinters are present in the fractured area. Skiagrams should be employed for the determination of these factors. It is permissible to count upon the vitality of these bony fragments and of the traces of periosteum by which they are accompanied, which

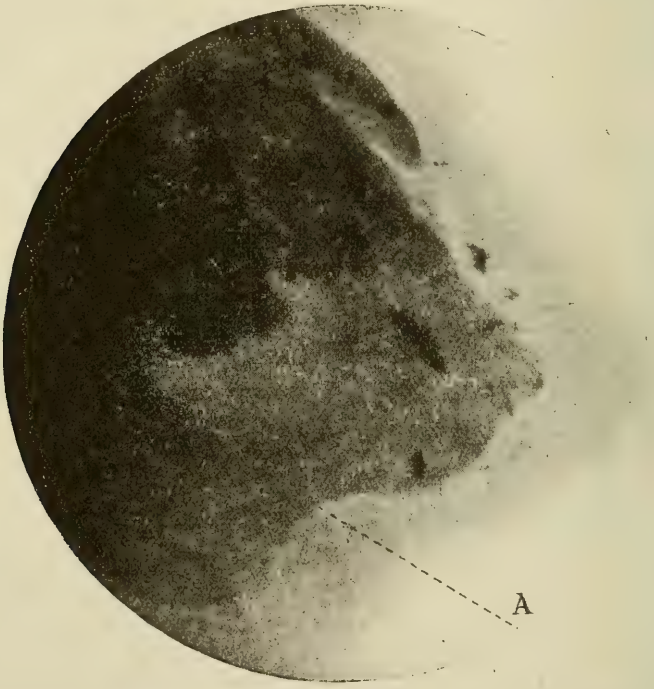



FIG. 61.—Same case as fig. 60. Skiagram of the united fracture.

play a very important part in effecting union. The action of the immobilisation apparatus should be confined to maintaining the principal fragment in good occlusion. No attempt should be made to get the posterior fragment into occlusion; it has already undergone spontaneous displacement by which it has

been brought closer to the principal fragment. To interfere with this displacement is to endanger union. Moreover, is there any decided advantage attaching to its retraction? There is no very great inconvenience in the fact that the last inferior molar articulates with the second superior molar. This represents

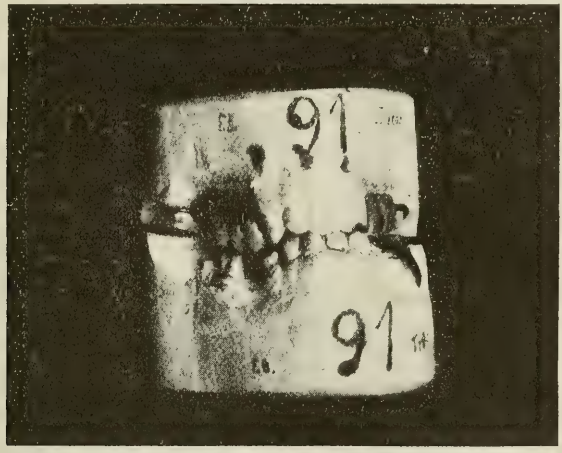



FIG. 62.—Same case with prothetic apparatus.

a very slight degree of malocclusion, and one which is easily remedied later.

For purposes of retention bridges or splints should be employed. We ourselves prefer the apparatus shown in fig. 64, which, in cases of this class, is used solely as an immobilisation agent. It has certain advantages over other immobilisation mechanisms. The posterior fragment is connected with the splint attached to the principal fragment by a double sliding bar, which resists mobility in the transverse and the vertical sense, but permits the spontaneous forward

movement of the posterior fragment, a movement which is very favourable to the co-adaptation of the

FIG. 63.—Photograph of the patient whose fracture is reproduced in the preceding illustrations. The fracture united spontaneously, the posterior fragment coming forward. Flattening of the angle of the fractured side.

fragments and to ultimate union. The double screw is employed solely to fix displacement, never to provoke it.

Where the bony loss is 1½ to 3 cm. in length and is

shown by skiagrams to be absolute, especially where it includes the basilar portion of the bone, distinct advantage is derived from bringing the posterior fragment forward. The interval between the fragments is lessened or may even be filled, and the chance of evading ultimate pseudo-arthrosis is increased.

It is important to realise that this compensatory forward movement by mechanical means coincides with a natural impulse on the part of the posterior fragment which may be counted on in the vast majority of lateral fractures. The following clinical history is interesting in this connection.

The patient was wounded in Morocco in July 1914; his mandible was fractured but united well. The fracture-site is bounded by the left lateral incisor on the one hand, and by the first or second molar on the other. Hence the amount of substance lost must equal at least three teeth. Although no mechanical measures were employed, perfect union with formation of callus resulted. There is a slight deviation of the mandible towards the fractured side; occlusion is satisfactory.

It is with the object of obtaining results similar to these that the apparatus shown in figs. 64 and 65 is designed. By a system of sliding rods and screws the fractured surfaces are drawn together and the fragments are at the same time maintained in rigorous immobility during the entire period of treatment.

By releasing the screw the apparatus may from time to time be sufficiently loosened to permit of examination of the site of fracture. The apparatus is easy of construction and of application; it is clean; and it is very well tolerated by the patient. It should be applied as early as possible, and during the first week of its application the screws should be gradually tightened until the fractured surfaces meet. The results are verified by examination of the fracture site and by skiagrams.

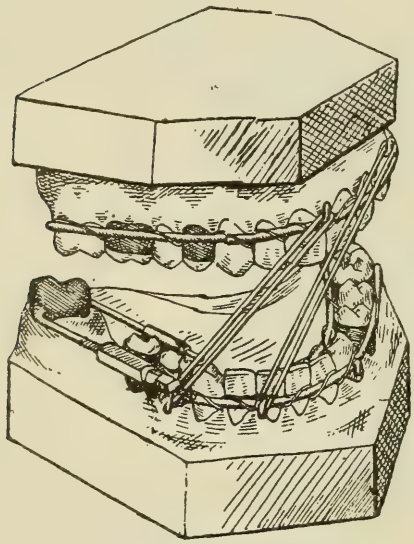


FIG. 64.—Mechanism employed to move the posterior fragment forward, intermaxillary force being exercised at the same time. The mechanism consists of a threaded rod, one end of which is attached to a crown which covers the tooth on the short fragment, the other end runs through a tube soldered to the alignment wire on the principal fragment. By tightening the screw and counter-screw in front of the tube the posterior fragment is drawn forward. On the lingual side a somewhat similar mechanism is placed, but this is not furnished with screw and counter-screw.

The action of the sliding bars is supplemented by intermaxillary traction by means of elastic bands, whose object it is to prevent lateral deviation of the principal fragment. Both tractions are maintained during the entire period of treatment. Once the fragments have been brought

together, the screws of the sliding bars are not again released.[1]

Fraction of the posterior fragment does not demand a very resistant anchor point. A single tooth is suffi-

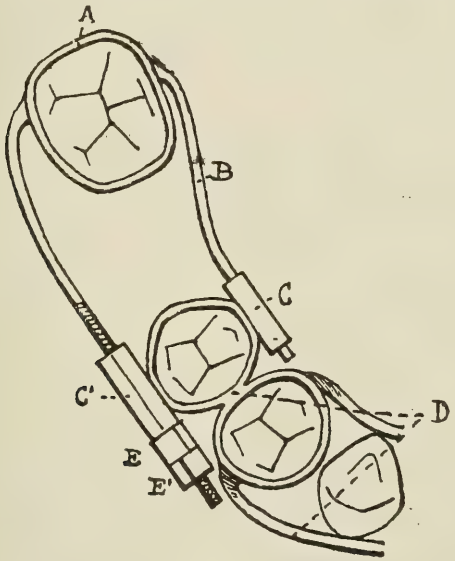



FIG. 65.—Mechanism to bring forward and to immobilise the posterior fragment. The tooth on the posterior fragment is fitted with a band *A* attached by cement. On the lingual face of this band a German silver wire *B* is soldered, which runs through the tube *C*, which is soldered to the anchorage *D* attached to the principal fragment. The mechanism is repeated on the labial face of the band *A*, with this difference, that the extremity of the wire running through the tube *C'* is threaded. A screw *E* and a counter-screw *E'* are fitted to the threaded end of the wire at its exit from the tube. By tightening the screw *E*, the posterior fragment is drawn forward, while at the same time an absolute immobility is maintained.

cient, even though very much loosened or broken. The anchor appliance itself, however, should be very strongly attached. Bands are not sufficiently resis-

[1] Instead of intermaxillary anchorage by means of elastic bands, the apparatus described later under the name of "active crank" may be employed. The method yields excellent results.

tant; crowns should always be used, and it is frequently better to reinforce them by screws going well down into the pulp cavity and the distal root canal.

This mechanism not only reduces the fracture, but it so absolutely immobilises the fragments that to employ a special immobilisation apparatus is unnecessary.

It is a remarkable fact that, where there is large loss of bony substance, the deformity of the mandibular arch is much less than would be supposed. This is due to the tendency of the posterior fragment to move forward and thus to occupy the place of the missing bony portion.

Then again, the establishment of occlusion is greatly aided by the extreme mobility of the temporo-mandibular joints. These movements are determined and fixed by the intermaxillary traction of the elastic bands, and this traction should therefore be very judiciously employed.

By this method we have in some cases effected compensation for loss of bony substance corresponding to two molars (about 2½ cm.) with satisfactory union of the fragments. Owing to the specific adaptive quality of the temporo-mandibular joints, in no case has malocclusion resulted. Naturally, the results are best when the loss of substance is least.

The principle of the method may at first sight seem to be somewhat daring, but it is justified by results. The fact that occlusion is preserved in spite of the shortening of the body of the mandible, removes the

only objection to the method which might have been advanced.

The measures employed by stomatologists for the correction of malocclusion are various. Expansion of the mandible is a common orthodontological procedure. Elongation of the callus, as described in connection with median fracture, may also be employed here, and we are convinced that by this means it is possible to compensate for a bony loss in excess of 3 cm.

Recourse to instruments of prosthesis is necessitated by the nature of certain cases. Where half the lower dental arch closes inside the upper arch, thus losing all contact with the corresponding teeth above it, it is a simple measure to line the upper arcade with triturating surfaces in such a way that they articulate with the teeth of the lower jaw (P. Robin).

A mechanism of this kind, if only on account of its method of equilibrium, is eminently stable, and its efficacy does not depend upon the presence of the teeth.

Moreover it should be borne in mind that the absorption of the bone, consequent upon the loss of the teeth, is always very much more marked in the case of the maxilla than of the mandible. This physiological change has the favourable effect of restoring to a certain extent the harmony between the sound upper jaw and the contracted lower jaw.

We have therefore every right to assert that the future of these cases is as assured as their present. Where there is pseudo-arthrosis, on the other hand, the patient must sooner or later become disabled.

Occasionally the method is unsuccessful and union is not obtained. But even in cases such as these the treatment has certain favourable effects. The forward movement of the posterior fragment permits the employment of osteo-synthetic measures in place of the bony graft, prognosis in the case of the latter method being far less favourable than in the case of the former.

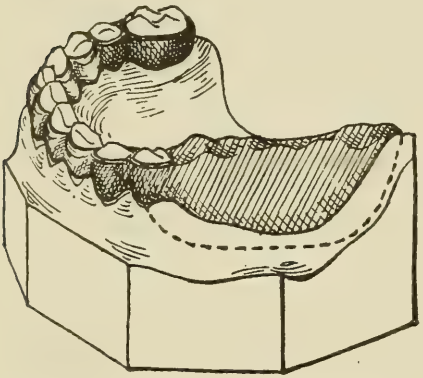


FIG. 66.—Immobilisation apparatus for lateral fracture. There is no anchorage point on the posterior fragment. The cap which encloses the posterior fragment descends very low especially on the lingual side. It is soldered to a double splint with anchor bands which is cemented to the teeth of the principal fragment. This constitutes an efficient method of anchorage.

(*b*) *The posterior fragment offers no anchorage point.* — Where the posterior fragment is accessible, it should be enclosed in a cap which descends very low, particularly on the lingual side. This cap is soldered to a double splint with anchor bands, which is adjusted and cemented to the larger fragment.

The posterior fragment is applied to the cap which covers it by the tonicity and the contractions of the elevator muscles, a satisfactory immobilisation being thus obtained (fig. 66).

Where the mandible shows a tendency to lateral

deviation, intermaxillary anchorage as described above should be employed.

To render the method more efficient, the posterior splint may be attached to that on the principal fragment by means of a device with a double bolt, which permits of the posterior splint being raised for purposes of inspection or cleansing. This instrument is described in detail later.

Where the loss from the posterior fragment is so extensive that immobilisation is not possible, the clinical appearances resemble those of fracture of the angle, and the therapeutic indications are the same.

2. **Old Lateral Fracture** with slight or medium loss of substance (1½–3 cm.).—*Where the posterior fragment presents a point of anchorage*, a mechanism should be employed to bring the fragments together. We have observed the union of lateral fracture with large loss of substance in cases where treatment had not been instituted until four months after the date of injury.

In all cases, including those in which union is not obtained, the bringing together of the fragments greatly facilitates surgical intervention. It frequently permits of the substitution of osteo-synthetic methods, which may be regarded as constant, for that of the bony graft, the results of which are always uncertain (see chapter on Surgical Treatment).

*Where the posterior fragment is deprived of teeth and, as is usually the case, is displaced forwards and upwards*, the first care should be to get it into normal position. This is effected either by a mechanism in

which the force is passive and resides in a spring, or by means of the apparatus shown in fig. 67. In the latter the action of the spring is supplemented by intermittent pressure from a jointed crank, which is brought to bear upon the posterior fragment each time that the elevator muscles contract or under

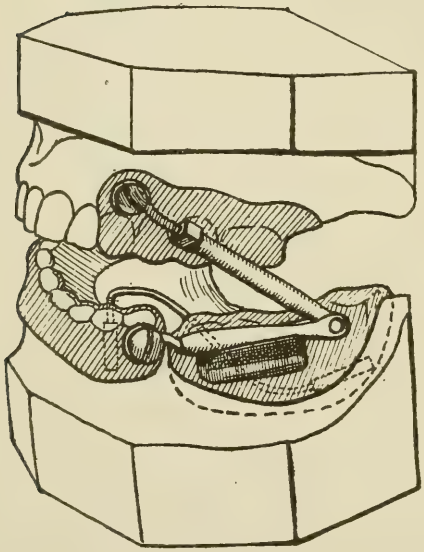


FIG. 67.—Apparatus for the reduction of the posterior fragment when it is displaced upwards and forwards (G. Villain). The posterior fragment is enclosed in a splint the internal face of which descends very low along the whole lingual face of the fragment. This splint is kept in position by a spring of low power on the lingual side. When by the action of the elevator muscles the jaws are brought together, the lower arm of the crank comes to rest in a groove on the vestibular surface of the splint. The rod of the crank is threaded and fitted with a screw, by means of which the action of the crank may be regulated according to need.

the simple influence of their tonicity. The apparatus is designed by G. Villain.

When reduction has been obtained, union between the posterior and anterior splints is established by uniting them with solder and with bolts, as shown in fig. 66.

Where the posterior fragment is inaccessible, the fracture is treated on the lines of fracture of the angle.

**3. Old Lateral Fracture with Extensive Loss of Sub-**

**stance** (over 3 cm.).—(*a*) *Recent fracture.* Where the posterior fragment possesses a tooth or a root suitable for an anchorage point, the fragments are first trained into a position of normal occlusion and then immobilised. By these measures both the deviation of the fragment and cicatricial retraction are avoided and subsequent prosthetic treatment is facilitated. The anchorage upon the posterior fragment should be carried out with extreme care. The best method is by a screw- or a stud-crown.

Where the posterior fragment is toothless, immobilisation in occlusion is advised.

(*b*) *Old fracture.*—Where, as so frequently happens, these fractures have not been previously immobilised, they should be treated in the same way as recent fracture. Until such treatment has been vigorously pursued for at least three mouths, pseudo-arthrosis cannot be considered definitive and should not be treated as such.

*C.* **Fracture of the Angle.**—The possibility of influencing the posterior fragment is here very limited. The principal fragment, on the other hand, is readily immobilised by attachment to the upper jaw. This measure prevents any movement of the fracture-site which, apart from loss of substance, is one of the chief causes of pseudo-arthrosis at the angle and is a far more powerful factor than muscular or tendinous intervention (figs. 69 and 70).

Once again we emphasise the fact that immobilisation in occlusion has always been very well tolerated

by our patients. We have never observed infective phenomena such as those formerly described under the name of buccal cachexia. This may be due to the fact that the instrument permits of scrupulous cleanliness. Moreover, we have never found nutrition seriously affected. A liquid or semi-liquid diet is given which, after a little practice, is readily taken. About every fourteen days the ligatures are removed and the fracture site and the movements of the temporo-mandibular joints are carefully examined. This opportunity for minute cleansing of the buccal cavity is not neglected. Closure of the jaws has never been observed, not even in cases which had been immobilised for several months. The most we have ever seen has been a slight articular stiffness which disappeared after a few days of normal function.

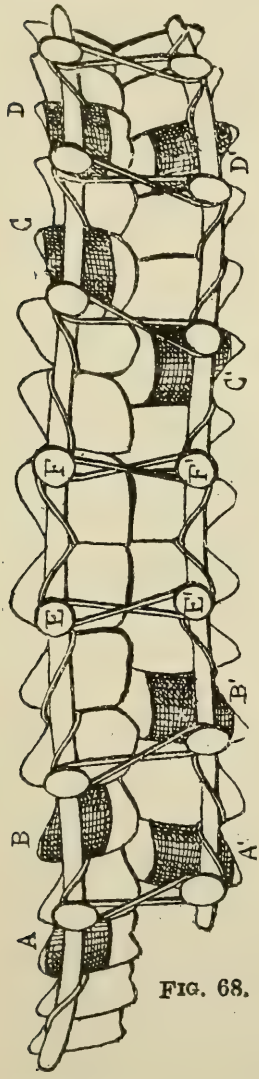
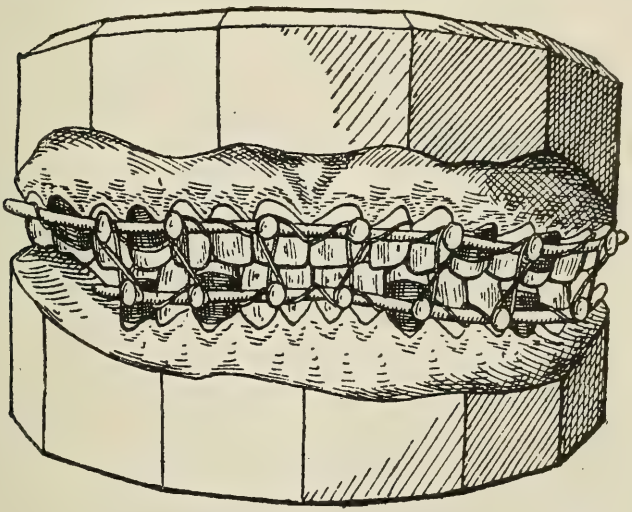


FIG. 68.

To avoid immobilisation in occlusion a form of retention apparatus has been suggested by certain authors. This consists of a principal splint firmly anchored to the teeth, to which a posterior splint is attached by means of bolts. The

posterior splint encloses the ramus and is fitted to it as exactly as possible. This apparatus is shown in fig. 71.

The construction of an apparatus of this nature is always a delicate matter, and it is especially so where the jaws are constricted. Moreover, the immobilisa-



FIGS. 69 and 70.—Apparatus for immobilising the jaws in occlusion. Metal wires with spurs are attached to the two arches. They are anchored by at least four bands, *A*, *B*, *C*, *D*, which are adjusted and cemented, and by ligatures of brass wire by which all the teeth are attached to the anterior arch. At intervals of about two teeth, spurs (*E*, *F*) are soldered to the two alignment wires. By means of ligatures of brass wire in figure of eight, the spurs are united and absolute immobility is obtained.

tion of the posterior fragment by this method appears to us very precarious. As a matter of fact, the posterior splint can enclose only the anterior border and a portion of the lingual surface of the ramus. In our opinion there is no guarantee that immobilisation is effected. The apparatus may perhaps be indicated in

angular fracture with slight loss of substance, though these fractures frequently unite without mechanical help. But its use in fracture with large loss of substance is utterly condemned, particularly as an apparatus of this kind has the supreme drawback of opposing the natural compensatory forward movement of the ramus, a movement which is so entirely favourable

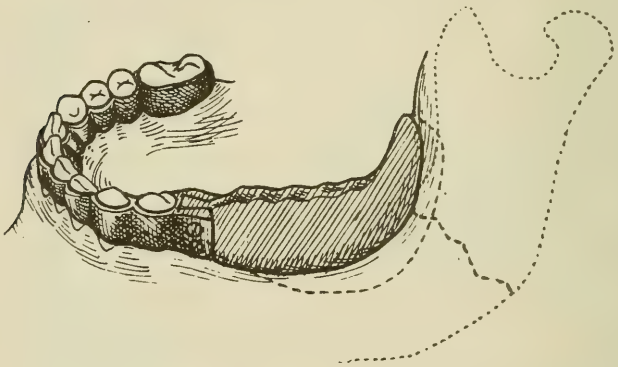


FIG. 71.—Mechanism for the immobilisation of the posterior fragment in fracture of the angle with slight loss of substance. The splint which covers the posterior fragment (ramus) is carried as high as possible up the anterior border of the ramus, and descends as low as possible along its lingual face. It is attached to the principal splint by a dove-tail joint and bolts. It is removable, thus facilitating inspection of the fracture site and cleanliness.

to the co-adaptation of the fragments and, in consequence, to the formation of the callus.

*D.* **Fracture of the Ramus.**—*Simple fractures without displacement* frequently unite spontaneously. We have seen a large number of cases in which masticatory movement had been restored without therapeutic intervention. The course of the projectile, however, showed conclusively that fracture of the ramus had

indeed taken place. In cases of simple fracture without displacement we confine ourselves to a " watching treatment." The patients are closely watched; modifications in the articulation of the teeth are especially looked out for; and measures are adopted to guard against closure of the jaws. For the latter purpose we advise, wherever necessary, mechanico therapeutic dilatation as employed in the treatment of myotonic constriction. During the intervening periods the jaws should be kept apart by a wooden wedge inserted between the dental arches.

*Fracture with displacement* demands a twofold treatment: to correct the deformity of the mandible and consequent deviation of the dental arches; and, by immobilisation of the jaws, to maintain this correction. Further, rigidity must be excluded.

These objects are best obtained by the method shown in fig. 72.

Both the upper and lower dental arches are fitted with alignment wires of the kind employed to obtain immobilisation in occlusion. Between the last molars of the fractured side a wedge is introduced which serves to keep the jaws about 2 cm. apart. The jaws are united by ligaturing the two alignment wires together. On the sound side elastic bands are stretched, the number of which varies according to the amount of force which it is desired to employ. This mechanism recalls the " open-mouth " attitude recommended by Claude Martin in fracture with vertical discrepancy of the fragments.

The technique of this apparatus is very simple. The wedge of wood introduced between the molars is the fulcrum upon which the entire body of the mandible moves. Movement is induced by the elastics stretched between the jaws on the sound side, and is continued until the space between the dental arches is eliminated.

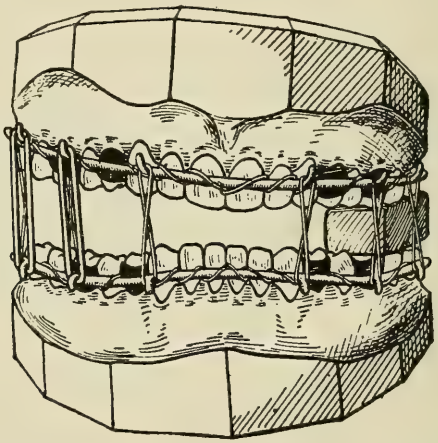


FIG. 72.—Mechanism for reduction of fracture of the ramus with displacement. Immobilisation of the right side is effected by means of simple ligatures, a wedge of wood being inserted between the last molars. On the left side, similar ligatures are reinforced by elastics, the action of which tends to counteract the gap between the teeth in occlusion.

Immobilisation with the open mouth has the further advantage of effectually counteracting osteo-fibrous constriction.

It may possibly be objected that the movement of the mandible might have the effect of shifting one or other of the fractured surfaces and thus imperilling union.

The answer to this objection lies in the fact that

the process of prolongation, to which the callus is subjected during formation, is modified in such a way that slight resistance only is offered to the co-adaptation of the fragments. Moreover, pseudo-arthrosis is a far less frequent complication here than in cases where the fracture is situated at the level of the horizontal branch. In the latter case the fracture of the lever results in almost absolute functional incapacity.

Pseudo-arthrosis of the ramus, excluding total or partial destruction of the bone, is perfectly compatible with function. As an instance, the case of a man who had lost an entire condyle with its neck and who was perfectly able to masticate his food, may be quoted. He was able to resume his military service.

The apparatus shown in fig. 72 seems to us to be the method *par excellence* of dealing with these cases, for it serves to reduce the fracture while at the same time immobilising the fracture site. We must in fairness, however, record the results obtained with the cranked mechanism (figs. 75 and 76), of which a detailed description will be given later. This mechanism is at first employed to reduce the fracture ; later, by blocking the screws of the crank-head it is used as retention apparatus.

Fracture of the condyle with loss of substance, whether complicated or not by destructive lesion of the glenoid cavity, presents a symptom-complex identical with that associated with fracture of the ramus, and is amenable to similar treatment.

We ourselves have never seen a case of fracture of both rami with displacement of fragments, but it is logical to assume that the characteristic attitude of such a fracture would consist in a bilateral interval between the upper and lower teeth. Treatment would consist in a suitable modification of the method just described.

### IV. Treatment of Pseudo-arthrosis

Fracture presents classical pseudo-arthrosis when union has not been effected by prosthetic treatment of at least six months' duration. The restorative mechanisms which we are about to describe are designed solely to meet the requirements of such cases. But, as G. Villain has pointed out, this mechanical treatment must be regarded as a step only in the general management of pseudo-arthrosis. The condition is amenable to surgical treatment, to which there is a growing tendency to refer it.

Pseudo-arthrosis is a frequent, though not a fatal, accompaniment of fractures complicated by large loss of bony substance. As we have shown, a loss of substance up to 3 cm. cannot under suitable treatment be regarded as a bar to union.

In this chapter we propose to deal with pseudo-arthroses due to very large loss of substance (over 3 cm.). These are very varied in character, but they may be classed under five principal headings :

1. Median pseudo-arthrosis.

2. Pseudo-arthrosis of the body, with posterior fragment suitable for purposes of anchorage.

3. Pseudo-arthrosis of the body, with no posterior fragment or one useless for mechanical purposes.

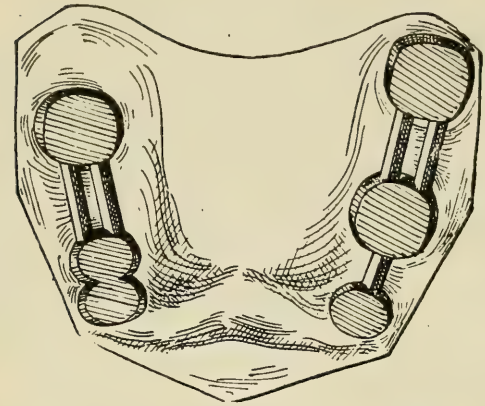
4. Pseudo-arthrosis of the ramus, with loss of substance at the temporo-mandibular joint.

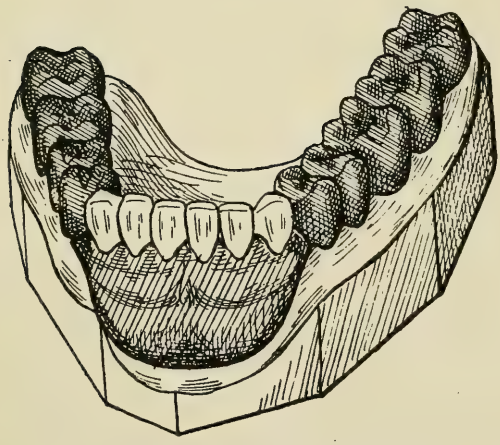
5. Extreme cases, with loss of substance corresponding to the entire body of the mandible with all its teeth. These are cases where the comminution is extreme and which are outside classification.

All these classes of lesion are accompanied by static and dynamic modifications, by which function is very much disturbed or even destroyed.

In median and paramedian pseudo-arthrosis the fragments are equal or approximately so, and are separated by a considerable interval. They tend to approach the median line in such a way that the teeth lose all contact with the corresponding teeth above them. The free extremity of each fragment has lost all elevator power and to so marked an extent that, even where dental occlusion is re-established, masticatory movements are accompanied by the mechanical depression of the fragment. Hence the derangement of function is considerable; it is no exaggeration to say that it is diminished in the proportion of 50 per cent.

Very similar conditions prevail in the case of lateral pseudo-arthrosis. The principal fragment, being markedly displaced to the fractured side, is useless for mastication, while the posterior fragment, being





FIGS. 73 and 74.—An apparatus for use in median pseudo-arthrosis, the lateral fragments possessing teeth. The teeth are covered by cylindrical crowns, attached to them by cement and united to one another in such a way as to form two solid anchorage blocks. These anchor blocks are carefully adjusted and are then enclosed very exactly in two telescopic gutters. The latter depend largely for their support upon the lingual face of the bone, where they are prolonged as far as possible both backwards and downwards. They are united by a rigid median base of great resistancy, upon which the prosthetic instrument, which is intended to fill the gap left by the substance and teeth lost, is fixed. In our view this mechanism is infinitely the best for the treatment of this class of case. Its stability is greater than that of simple removable apparatuses. On the other hand, it does not shorten the life of the teeth as does the bridge. Its anchorage is comparatively free, and the strain to which it is subjected is distributed over a large area of the mandible.

displaced either inwards or outwards, is in no better condition.

Pseudo-arthrosis of the ramus has a somewhat better prognosis, the reason for which will appear later.

The greater number of the mechanisms for the

treatment of these conditions are dependent for their application upon the presence of a certain number of teeth. Where there are no teeth, the infirmity is almost irremediable. For this reason mechanisms should be chosen, the anchorage of which excludes traumatic conditions such as must inevitably hasten the loss of the teeth.

**Median Pseudo-arthrosis.**—A mechanism intended to remedy median pseudo-arthrosis should fulfil two requirements: it should maintain the lateral fragments in occlusion, and it should derive from them a support sufficient to assure the stability of the replacement mechanism.

The first qualification is fulfilled by mechanisms constructed on a model presenting normal occlusion. We assume that the fragments have undergone preliminary orthognathic treatment, and that they may be readily got into positions of normal occlusion.

The question of anchorage is a debatable one. Some authors connect the two fragments by means of a bridge, strongly cemented to the teeth by means of crowns, which are soldered together. Others prefer to cap the teeth of each fragment and then strongly to unite the caps, thus creating two resistant anchor blocks, to which a removable median piece is attached by various methods.

At first sight the bridge appears the better method of the two, for it effects perfect immobilisation while at the same time conveying the subjective impression of restored function. Experience shows, however,

that the abnormal mobility of the fragments leads to increased activity of the alveolo-dental articulations, which inevitably terminates in the loss of the teeth.

For this reason we prefer a removable mechanism or, better still, a mechanism part of which is fixed and part of which is removable. By this means the strain upon the dental supports is reduced to a minimum. The most effective apparatus is that shown in figs. 73 and 74. The method of anchorage is entirely satisfactory. Further, owing to the fact that its internal margin descends very low on the lingual side, the base of support is broadened and the natural movement of lingual deviation of the fragments is utilised as the method of fixation.

Where one fragment is toothless, the results of mechanical treatment are obviously more precarious. In such cases the defective anchorage may be assisted by broadening the base of support and by employing an intermaxillary spring such as that shown in fig. 38.

Where both fragments are toothless, the base of the plate should enclose the fragments very exactly and should extend as far back as possible upon the lingual side. The springs may be strengthened by a fragment of piano-wire slipped into the lumen. They should be placed with their convexity forward.

**Lateral Pseudo-arthrosis.**—Where the posterior fragment bears one or more teeth, there is always the temptation to effect connection with the principal fragment by means of a fixed bridge. This method may be employed with advantage where temporary immobilisa-

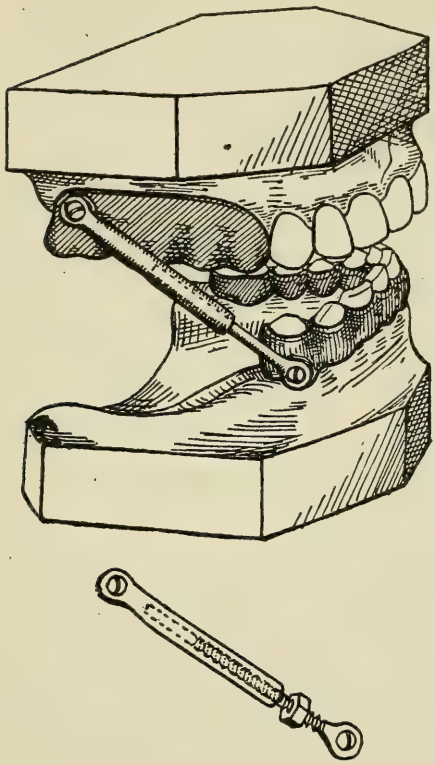
tion is required with a view to obtaining union. But in lateral pseudo-arthrosis, where the mechanism employed should have the character of a definitive restorative measure, it is not advisable.

The posterior pillars of a fixed bridge are unlikely to resist for long the very considerable strain which is put upon them during mastication. Hence it is advisable in cases of this sort to have recourse to a type of mechanism which is partly fixed and party removable.

The apparatus should be designed upon lines similar to that shown in fig. 73. The posterior fragment is very exactly covered by a splint which covers not only the teeth, but also the lingual face of what remains of the body, angle, and ramus. G. Villain advises the incision of the vestibular cul-de-sac in the retro-molar region, performed in such a way that a cul-de-sac is formed on the external surface of the angular region of the mandible. A prolongation of the base of the plate is slipped into this cul-de-sac, which gives an excellent support. By this means a very large area of support is obtained. The sound teeth of the principal fragment should be treated similarly to those of the lateral fragment (fig. 73).

The stability of a mechanism on these lines is usually entirely satisfactory. It may, however, be reinforced by pins inserted at intervals in the dental spaces, or by supplementary hooks which hold the teeth together.

**Lateral Pseudo-arthrosis, with total loss of the Posterior Fragment or its disability for mechanical purposes.**—The



**Figs. 75 and 76.**—Active and passive cranks.

Fig. 75.—Passive crank for use in lateral pseudo-arthrosis, the posterior fragment being absent or useless for prosthetic purposes. The four last teeth of the right maxilla are covered by a cast silver cap splint which is firmly cemented to them. To the posterior portion of this splint on the labial side, the cylinder of the crank is attached. The attachment is by means of a joint permitting movements of circumduction. All the teeth of the mandibular fragment are enclosed in an open cap splint to the extremity of which, corresponding with the site of pseudo-arthrosis, the piston rod of the crank is attached. This crank-head is able to perform movements of circumduction identical with those of the crank-head on the upper splint. As the jaws are closed, the rod telescopes nto the tube. Its length is calculated in such a way that the end of the rod reaches the bottom of the tube at the moment when the jaws are in occlusion.

Fig. 76.—Active crank. This crank differs from the one shown in fig. 75 in the fact that its rod is threaded and is furnished with a screw which, in movements of occlusion, touches the orifice of the tube. By altering the position of the screw, the crank may be brought into action before the end of the rod reaches the bottom of the cylinder. By this means it is possible to determine empirically the length which the rod should have in order to produce a given effect. A passive crank may then be constructed which will present the maximum of efficiency.

therapeutic problems presented by pseudo-arthrosis of this nature are very complex.

In each of the preceding classes of case it has been possible to re-establish a certain solidarity between

the fragments, and by this means to obtain a sufficiently satisfactory mandibular function. Here, on the other hand, we are faced with a single fragment, which has lost all connection with one temporo-mandibular articulation, and which, in consequence, possesses an irreducible tendency to lateral deviation, thus losing all functional ability.

It has been held by some that an apparatus maintaining the normal occlusion of the teeth during functional activity would meet the requirements of the case. Other authors have believed that such a therapy represented the minimum of treatment, and have sought to remedy the fracture of the mandibular lever, either by the creation of an artificial temporo-mandibular joint to which the free end of the fragment is connected, or, by transmitting to the fractured extremity sufficient elevator force (flexible cables) for the performance of movements of mastication, equal to those performed by the rest of the mandibular fragment.

Up to now sufficient evidence in regard to the latter method has not been forthcoming. There is, however, a well-proved method of reduction in these cases which has been described by G. Villain,[1] who calls it a "crank."

The crank is an apparatus which depends on intermaxillary force. It is anchored to the fixed bony mass of the upper jaw, and reacts upon the mandible or one of its fragments (figs. 75 and 76).

[1] G. Villain, "Traitement physiologique des fractures et des luxations de la mâchoire," *Odontologie*, August 30th, 1916.

The mechanism consists of a rod which telescopes into a tube. Rod and tube are attached by means of removable splints, the tube to the upper jaw, the rod to the lower, or inversely according to the requirements of the case. The heads of the crank are attached to the splints by joints, which permit of movements of circumduction upon the attachment screws, in such a way that elevator and depressor movements are not interfered with. If a little play is allowed to the heads of the crank, movements of circumduction may also be performed.

The mechanism of the apparatus is best understood by studying its action in a given case.

The mandibular fragment bears a splint, to the free end of which the rod of the crank is attached. The tube is attached either to a fixed splint or to a removable apparatus upon the maxilla.

During depression of the mandible there is a tendency on the part of the fragment to lateral deviation, but this is possible only within the very narrow limits permitted by the laxity of the crank heads. When the jaw is elevated, the rod plunges into the tube, and the length of the rod is so calculated that its extremity touches the bottom of the tube at the moment when the jaws are in occlusion. The effect is to force the teeth of the lower jaw into occlusion, and to maintain them in that position.

This is the passive crank employed for the reduction of deviations which are readily amenable to treatment. Where correction of the deviation is more difficult, the

active crank is preferable. This differs from the passive crank only in the fact that the rod is threaded and furnished with a nut. By screwing the nut towards the orifice of the tube the latter is arrested before the position of occlusion is reached. Thus, at each elevation of the mandible a degree of pressure, which varies in accordance with the position of the screw, is exercised, the effect of which is to propel the mandibular fragment into good position.

As soon as the displacement becomes amenable the threaded rod is replaced by a smooth one.

In certain special cases it is necessary to increase the length of the piston stroke, and for this purpose the elbow-crank (fig. 77), the jointed crank (fig. 78), the crank with horizontal attachments (fig. 79), are all employed. Where it is desired to modify the centre of rotation, the crank is mounted on vertical prolongations.

The crank is usually well tolerated and its therapeutic value is incontestable. It appears to act as something more than a simple guide ; the connection thus established between the jaws on the fractured side serves as a kind of support to the free extremity of the mandibular fracture.

The action of the crank is intermittent and is exercised only at the moment of muscular activity. In such cases as the one under discussion, the crank is infinitely superior to the old method of guides or of intermaxillary elastics.

Such is the apparatus usually employed to remedy this grave form of pseudo-arthrosis.

The apparatus reproduced in fig. 81 was designed by M. Bosano, a surgeon dentist and one of our clinical assistants. In our view it represents a very happy modification of the crank. It is, in fact, a jointed crank, the cylinder being replaced by a metal splint the upper surface of which is furnished with articulations which interdigitate with the teeth of the upper

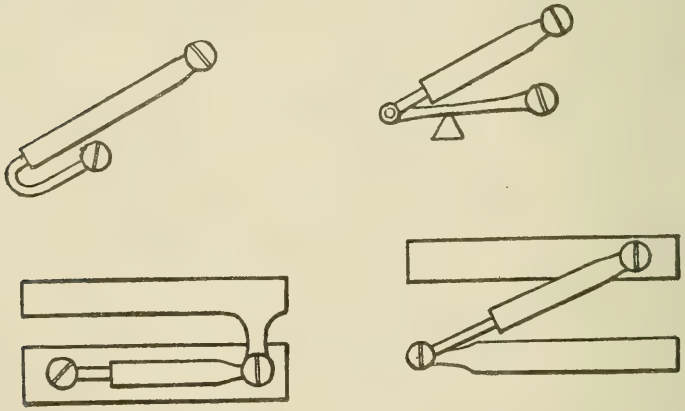


FIG. 77.—Elbow crank.
FIG. 78.—Jointed crank.
FIG. 79.—Crank mounted on horizontal prolongations.
FIG. 80.—Crank mounted on vertical prolongations.

jaw. This arrangement possesses all the advantages of the crank while at the same time re-establishing mastication upon the fractured side.

Among other apparatuses designed to the same end some, of which one is described by G. Villain, provide an intrabuccal artificial joint with which a rigid arm attached to the free extremity of the fragment articulates (see article in *Odontologie*).

We ourselves have designed an instrument upon

similar lines, the artificial fulcrum being fixed externally in the region of the absent temporo-maxillary joint. The bony lever is replaced by a rigid rod, which articulates with the artificial fulcrum and is firmly attached to the mandibular fragment.

Such an instrument as this should, in our opinion, be worn only during a meal.

At our suggestion MM. Granier, Bosano, and Audibert constructed several appliances conforming to a different principle. Here the elevator power which, owing to the break in mandibular continuity, had been lost, is reconveyed to the free extremity of the fragment.

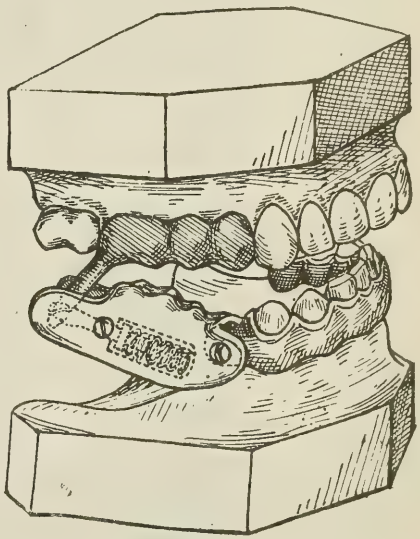


FIG. 81.—Jointed crank with articulated surfaces. The lower arm of this crank is a bar of cast silver with articulated surfaces which assist in mastication and serve to fix occlusion.

Fig. 82 represents an apparatus of this type. When the muscles contract, the flexible cable is extended; it draws upwards and into good occlusion the free extremity of the fragment, which is thus enabled to perform masticatory movements along its entire length.

These mechanisms are still very new and investiga-

tion concerning them is not complete. They are mentioned here only with reservation.

**Pseudo-arthrosis of the Ramus; Loss of Substance at the Temporo-mandibular Joint.**—These pseudo-arthroses are consequent upon fracture of the ramus

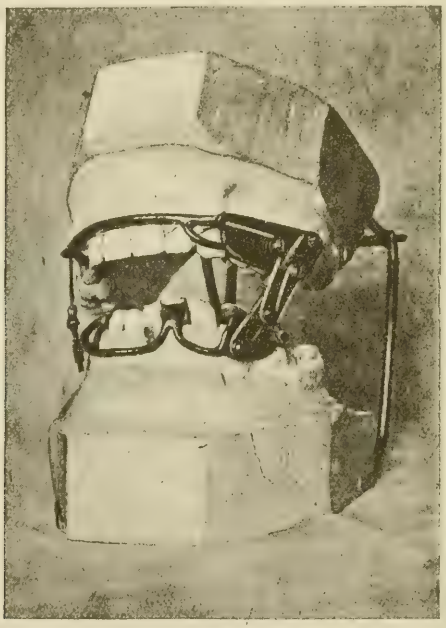


FIG. 82.—Apparatus for use in lateral pseudo-arthrosis. The chief feature of this apparatus is a flexible cable attached to the sound side which, at each movement of occlusion, is extended and transmits to the extremity of the fragment an appreciable force. Extension is effected by means of a system of pulleys. The apparatus may be rendered removable if desired.

with large loss of substance. They are characterised by malocclusion of a very specific type, which has been described in an earlier chapter (figs. 21 and 21*a*).

The malposition resembles that seen in extensive traumatic lesion of the temporo-mandibular joint

(destruction of the condyle and of the glenoid cavity). The method of treatment is equally applicable to both classes of case.

In pseudo-arthrosis of the ramus, when the elevator muscles are contracted the elevation of the mandible is not equal on both sides, in spite of the fact that muscular action is equal.

The fractured ramus drops in such a way that the fragments are brought together along the entire length of the breach. This movement is shared by the horizontal branch, with the result that the dental arches of the fractured side meet prematurely, the teeth of the sound side being separated by a varying interval. The elevator muscles of the sound side continue to contract, and occlusion is eventually effected upon this side also.

This occlusion in two parts is characteristic of the lesion. It may be associated with retraction and lateral deviation of the fractured side, but these displacements are secondary and always little marked.

The apparatus designed to remedy this pseudo-arthrosis should, in the first place, limit the action of the elevator muscles and the elevation of the mandible upon the fractured side. It should also, where necessary, force it into occlusion.

The crank with jointed arms and double stops, as described by Villain, corresponds to these therapeutic indications (fig. 83).

In elevator movements of the mandible the posterior arm encounters the superior stop, which conveys a

propulsive movement and thus corrects the lateral deviation and the retraction. The distal prolongation of the lower arm comes into contact with the inferior stop, thus preventing abnormal elevation of the mandible. Finally, when the mandible is in occlusion, the extremity of the rod of the crank comes to rest at the bottom of the cylinder and thus completes the action of the stops.

This description applies to the crank in its definitive form. It is frequently possible to employ this form from the first. It is, however, sometimes necessary, for purposes of examination and regulation, to employ the form shown in fig. 84.

In the latter, crank, arms, and stops may be modified in every kind of way to produce elongation or curtailment. The operator is thus enabled to alter the dimensions and relationships of the different pieces experimentally, and by this means to adjust the apparatus to the necessary requirements.

A "stop-guide" is also recommended by G. Villain. As, however, we have had no opportunity of testing it, we shall not describe it here.

We have already had occasion to mention a case in which complete disappearance of the condyle with its neck was not attended by functional derangement of any description. It is hardly probable that in a case of this kind the missing portion of bone could have been reconstituted. We must therefore assume a species of muscular adaptation to compensate for the missing bony substance. It is reasonable to assume

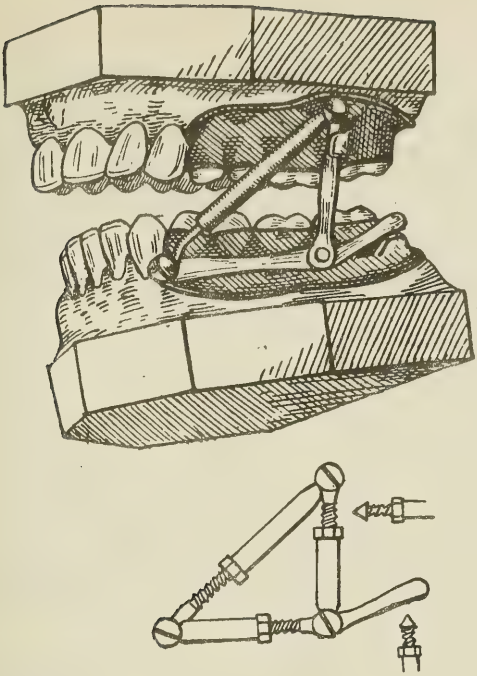


Fig. 83.—Crank with lever and two stops for the treatment of pseudo-arthrosis of the ramus or loss of substance at the temporo-mandibular joint. This is a passive crank (fig. 75) attached to two rigid arms, one vertical the other horizontal, which are jointed at the crank heads and jointed together. To the upper splint a stop is attached which, in movements of occlusion, bears on the vertical arm of the lever and produces a forward movement of propulsion. To the lower splint a stop is also attached which, in movements of occlusion, bears on the extremity of the horizontal arm of the lever, thus limiting abnormal tendency of the mandible to rise. The latter movement is due to loss of substance of the ramus or of the temporo-mandibular joint, and produces premature contact of the dental arches of the fractured side. The play of the lower arm of the lever counteracts this movement and regulates it in such a way that interdental contact is simultaneous along the entire length of the dental arches.

Fig. 84.—Active crank with lever and stops. This is a kind of preliminary to the form shown in fig. 83. The rods of the crank, lever arms, and stops are threaded and fitted with nuts. By this means the dimensions are varied and the form most suitable to the individual case is obtained experimentally. From the design obtained in this manner the definitive apparatus, as shown in fig. 83, is constructed.

that, after a given time, muscular adaptation of this kind may develop under the influence of the crank, and that the crank would then become superfluous. Hence the prognosis in these pseudo-arthroses would be more favourable than in the lateral and median forms. This, be it understood, is hypothesis ; experience in these cases is too recent for a categorical statement to be permissible.

**Loss of Substance amounting to almost the entire Mandible.**—It is cases of this class which make the greatest demand upon the ingenuity of the practitioner. We can only give the general lines upon which treatment should be conducted. Each case demands special mechanisms, and we give the results of our experience with a certain number of these.

To obtain an impression of the mandibular fragments is frequently a very complicated proceeding and one that requires several sittings. The chief endeavour should be to obtain as faithful a reproduction as possible of all fibrous bands and bony projections likely to favour retention.

The base of the mechanism should be in cast metal. It should take advantage of the slightest bony or fibrous elevation for purposes of anchorage. The artificial teeth are attached to it later by vulcanised india-rubber. Retention may be aided by springs attached to the upper jaw in the manner described above. In certain cases the crank with springs described by G. Villain (Interallied Dental Congress, 1916) is indicated.

A badly shattered jaw is sometimes accompanied by marked constriction of the buccal opening. This constitutes a serious obstacle to the taking of impressions and the application of mechanisms. In these cases the impression should be taken in several portions and the apparatus should be constructed in several pieces, in the manner described formerly by Claude Martin and Delair, and more recently by Martinier and Roy (*L'Odontologie*, 1916).

## V. Treatment of Malocclusion

Where malocclusion is due to vicious union as the result of large loss of substance, surgical intervention is indicated. Oblique osteotomy would appear to be the best method. It has frequently been practised by Sébileau with satisfactory results.

In other cases, notably the deviation known as *bouche de chantre de village*, the best method is by early prosthetic treatment.

The apparatus employed for the treatment of lateral fracture should always permit of intermaxillary anchorage, in order that any tendency to lateral deviation may be counteracted. The mechanism shown in fig. 64 fulfils this requirement.

Where the vicious position is already established, treatment is more complicated and is bound to take a long time.

The apparatus which most nearly corresponds to the indications is the crank.

It is not always indicated in the earlier stages of treatment. In certain extreme cases, where deviation is not readily remediable, the jaws should at first be immobilised by the apparatus shown in figs. 69 and 70. By this means the vicious position is partially corrected from the start. Later on the ligatures are tightened every eight days, in such a way that the dental arches are gradually brought into occlusion. Occlusion is maintained during a varying period, the ligatures being removed from time to time to ascertain the results of treatment.

The crank is not employed until the movements have become more supple and the reduction of the vicious attitude can be effected with slight manual effort.

The crank is intended to counteract the lateral deviation, which is more pronounced when the mouth is open. It should at the same time effect normal occlusion when the jaws are closed. Thus its function is that of a guide.

A passive guide (fig. 75) generally fulfils all requirements. It is attached to the fractured side in the usual manner, and as little play as possible is allowed to the articulations at the crank-heads as well as to the telescope. The latter is regulated in such a way that when normal occlusion is obtained the rod comes to rest at the bottom of the tube.

Occasionally two cranks are necessary, one at each side. By this means it is possible to counteract

strong muscular opposition, as well as to obtain a better occlusion (fig. 85).

In cases of this sort the lever-crank is very useful. It is a more resistant guide than the simple crank and is, for that reason, frequently indicated here.

The methods described give excellent results in this sense, that they rapidly reduce deviations which are sometimes very marked, while at the same time they permit of a practically normal diet. But it must not be supposed that a malposition corrected is always a malposition cured. Before an absolute cure is obtained, the muscular hypertonicity must be counteracted for a long time by the influence of the crank. Every now and then the apparatus is removed for the purpose of testing whether the patient is able to correct the vicious attitude spontaneously. Not until he has acquired the faculty of contracting his masticatory muscles synergically can he be regarded as cured and relieved of his crank.

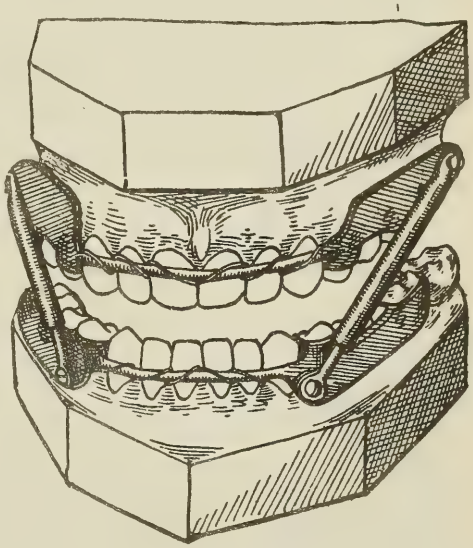


FIG. 85.—Double crank for the treatment of the deviation known as "bouche du chantre de village." These are passive cranks similar to those shown in fig. 75 *et seq.* They work as two active guides which counteract the lateral deviation.

After cure the patient should still be under supervision for a time, for his condition, similarly to that of mandibular constriction, is essentially prone to relapse. Moreover, the co-operation of the patient is not always to be depended upon.

On the slightest sign of relapse the crank is replaced. Lateral deviation may be prevented by using a lateral guide, supported by a bridge attached to the sound side.

The malocclusion consequent upon mandibular fracture is referable to two primary causes.

In some cases it is associated with very marked anatomical lesions of the mandible, deformities which are amenable to prosthetic treatment where union is not far advanced, or which demand surgical intervention if the ossification of the callus is definitive.

In other cases malocclusion is the outcome of dynamic derangement of the masticatory muscles, the lack of co-ordination in their action producing the specific distortion known as *bouche du chantre de village*. The length of time required for treatment depends upon the length of time the condition has lasted. Treatment should be purely prosthetic, and the most efficacious mechanism is the crank.

## VI. Mechanico-therapeutic Treatment of Myotonic Constriction of the Maxillæ

The method of treatment now to be described is more particularly indicated in the form of closure of the jaws most commonly observed, namely, the myo-

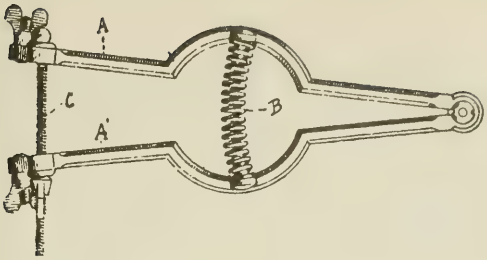



FIG. 86.

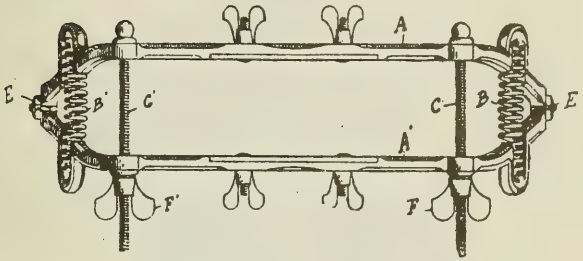



FIG. 87.

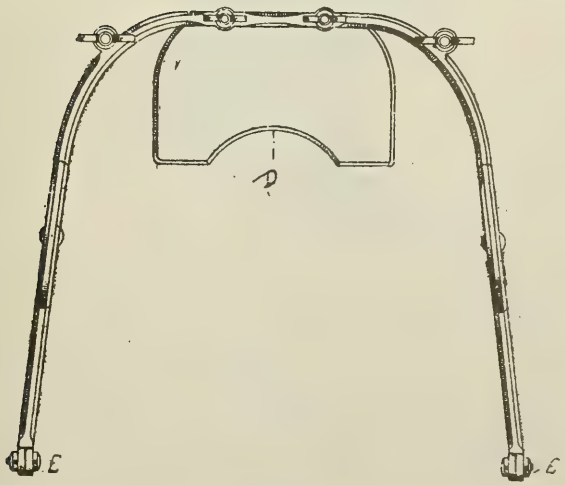



FIG. 88.

FIGS. 86, 87, 88.—*AA'*, metallic arches jointed at *EE'* and furnished with splints *DD'*, by which the power of the springs *BB'* is transmitted to the dental arches. *CC'*, threaded and graduated rods with flanged screw-nuts *FF'*, by which the action of the springs is modified. Their graduation shows the progress made.

tonic. If undertaken early, before sclerotic or cicatricial lesions have become definitely established, it is very efficacious in constriction due to myositis of the masticatory muscles and to lesions of the temporomandibular joint.

Our patients always receive mechanico-therapeutic

FIG. 88*a*.—Automatic mouth-opener, for the treatment of closure of the jaws.

treatment twice a day. Each sitting lasts for about half an hour, and the apparatus employed is one which we have had in use for some time and which is shown in figs. 87 and 88. Its qualifications are as follows :

The base of support is distributed over the entire length of both dental arches by means of special adjustable splints.

The springs which convey the expansive force are regulated by flanged screw nuts.

Each day's progress is registered by means of a graduated rod.

In our view it is essential, especially in myotonic cases, that the gap between the jaws effected at each sitting shall be maintained by means of a wooden wedge introduced between the teeth and kept there until the next sitting. This measure effectually counteracts the hypertonicity of the elevator muscles. It produces the "inverse attitude," a therapeutic principle regarded as of extreme importance by neurologists interested in acromyotonia.

## CHAPTER VI

### SURGICAL TREATMENT

In the last chapter the technique and the clinical results of prosthetic treatment were described. In mandibular, as in the majority of other fractures, operative treatment should not be resorted to until treatment by mechanical apparatus has failed. It is in fact indicated in pseudo-arthrosis alone.

For the last eighteen months we have been in charge of a maxillo-facial department with a minimum of 150 patients. During this period eighteen patients only have received surgical treatment. This is proof positive that we ourselves have carried out the principle which we advocate, namely, never to operate except in definitive pseudo-arthrosis.

Two forms of surgical intervention are indicated. Where it is advisable to draw the two fragments of bone together, osteo-synthesis should be practised. Where the loss of substance is very extensive, however, osteo-synthesis is either not attended by results or it yields results which are functionally imperfect. In such cases the method should be reinforced by the bony graft. The object of this book, however, is to describe the positive results of the treatment of war

wounds, and the number of bony grafts performed upon the mandible is too few to permit of definitive conclusions. For this reason the subject will be only briefly dealt with here.

Those of our cases in which osteo-synthetic methods have been employed have all been lateral fractures. This is due, not to special suitability of the condition, but to the fact that the method has not been indicated in the cases of median and retromolar fracture which have come under our notice.

Union is undoubtedly more frequent in median fracture than in other types. This is attributable to the fact that the equal length of the fragments facilitates their inclination towards one another. It is true that vicious union may result, but pseudo-arthrosis is excluded. It may be, too, that the tendency to intervention on the part of the muscular masses in the immediate neighbourhood is slighter. However that may be, one thing is certain, namely, that pseudo-arthrosis in median fracture is invariably associated with grave loss of substance, such as cannot be remedied by osteo-synthetic methods.

Similar reasons hold good in the case of fracture of the angle and of the ramus. These fractures either unite or the loss of substance is so extensive that osteo-synthesis is impracticable.

### I. Osteo-Synthesis

In the case of fracture of the limbs the bony extremities may be brought together in various ways: by

flexible ligature, metal ligature, bolts, etc. In fracture of the mandible several of these methods are excluded. The only permissible methods are ligature with metal wire, and the application of a screw-plate. The latter is preferable, because it procures a greater rigidity and a better co-adaptation of the fragments. We recognise, however, that after the fragments have been brought together, the maintenance of the jaws in occlusion by methods which we shall describe later, contributes very favourably to the contention of the fracture site, and for this reason we do not entirely reject the wire ligature.[1]

It must be understood that the indications for surgical treatment are exceptional. The special methods described in the previous chapter result in the union in good position of 90 per cent. of fractures with loss of substance, and 100 per cent. of fractures with no loss of substance. The results obtained in the maxillo-facial department of the medical centre at Marseilles are such that the proportion of patients returned to the army has never been less than 90 per cent., and has frequently reached 95 per cent.

## OPERATIVE TECHNIQUE

Here, as elsewhere, asepsis is essential, and the technique we are about to describe is formulated with the object of attaining it. But it must not be for-

[1] L. Imbert and P. Real, "Traitement des Pseudo-arthroses du maxillaire inférieur par l'ostéo-synthèse." *Soc. de Chir.*, March 29th, 1916, and Interallied Dental Congress, November, 1916.

gotten that union is obtainable even at an infected fracture site. Good results in the case of the humerus have been published by Dujarier, and we ourselves have effected union where a sinus existed at the site of operation. On the other hand, union by first intention is not invariably a therapeutic success. In the case of the mandible, the infective complications of osteo-synthetic operation are never serious. We have never lost a patient nor have we ever had cause for serious anxiety. Hence, where local infection is present it is rarely necessary to remove the metal plate; it is usually sufficient to remove the sutures.

**Age of the Fracture.**—At what stage is operation indicated? As we have shown, the surgeon should not intervene until pseudo-arthrosis is established. This condition depends either upon the amount of substance lost, which is not less than 2–3 cm., or upon the failure of prosthetic measures. The latter should have been employed under suitable conditions and should have succeeded in bringing the fragments together. A fracture in which the fragments are permanently separated may unite by the agency of bony projections, but the conditions are not favourable to union. To obtain union in obstinate cases an apparatus should be employed which will bring the fragments together. It should, moreover, be worn for a sufficient length of time. In our opinion the minimum is three months, dating from the moment when the lesions of the soft parts have so far progressed that complications on their part are no longer to be

anticipated. Thus, pseudo-arthrosis is not presented until after a period of at least six months. Intervention before this date does not expose the patient to any serious danger, but the results of such intervention must be regarded as surgically facile, seeing that union could have been obtained by means of mechanisms.

Should operation be postponed until infection is abolished ? Our answer is emphatically in the affirmative. Not that good results are not obtainable, but it appears to us purposeless to act in the presence of a suppuration which, to say the least, must prove inconvenient. Moreover, it is always easy to dry up the suppuration from a fracture, and the conditions presented by the mandible are more favourable than those of the majority of bones. A sinus in connection with a fracture is due to two causes, namely, the presence of dental caries or of a sequestrum. The mouth should be minutely examined by the stomatologist, and all fractured roots as well as those suspected of infirmity should be removed. Where, in spite of minute attention, the sinus does not close up, surgical intervention is indicated. Simple curetting, so frequently without effect in sinuses of the bones of the limbs, usually gives excellent results here. The channel is opened up, a small sequestrum, the root of a tooth, a tooth itself, removed, and the sinus closes in a few days. It is exceptional for a second curetting to be necessary.

Occasionally there is a hampering discharge, salivary

rather than purulent. This is remedied as follows. The little orifice is localised by watching the patient during mastication. The fine point of galvano-cautery is introduced as far as possible into the passage and is heated when the point is in position. If well cauterised in this manner, the fistula closes in a few days.

These minor interventions may with advantage be carried out during the prosthetic period of treatment. Where the rare opportunity occurs of taking over a patient from the first, by careful attention to these details the period of treatment may sometimes be reduced to four months. On the other hand, it must obviously be lengthened by the amount of time spent under less favourable conditions.

**Preparation for Operation.**—It is important that the buccal cavity should not be opened up by operative manipulation, for this is certain to lead to infection of the wound. It is difficult to prevent, however, where the root of a tooth is implanted in the extreme border of a fragment. For this reason we make a preliminary exploration of the fracture site. Roots at the extreme edge of fragments are carefully removed and the gum is allowed to heal, usually a matter of about fourteen days. In the first two operations which we performed, we opened the mucosa, but since taking these precautions such an accident has not occurred, not even where the denudation of the fractured surfaces was very extensive.

A second essential condition is the possibility of

bringing the fragments together. A reasonable loss of substance is presupposed; it should not exceed one or two teeth, in rare cases three. From this point of view prosthetic treatment, even where unsuccessful, is of extreme utility. In a previous chapter we have expressed the view that union is more important than occlusion, and that an efficient retention apparatus should bring the fragments together, thus effacing the loss of substance. It should prepare the ground for surgical intervention, for, as we shall show later, the success of osteo-synthetic methods in mandibular as in other fracture, depends upon the bringing together of the fractured surfaces. The superiority of osteo-synthesis does not depend upon the fact that it is applicable where there is large loss of substance. From this point of view its indications do not differ from those of prosthetic appliances. But the latter sometimes fail to effect union even where they have succeeded in abolishing the interfragmentary gap. The primary causes of this failure are not always appreciable, but the immediate causes appear to lie in the pointed configuration of the broken ends and the presence of a more or less thickened fibrous obstruction. The objects of operation are: to remove this obstruction, to make a fresh-cut surface to the broken ends, and to bring them into contact. It is evident that these results are more easily obtainable where the preliminary prosthetic treatment has fulfilled its purpose.

**Anæsthesia.**—In a former chapter we showed that mandibular fracture presents a mental zone of anæs-

thesia affecting the gum and mucous membrane of mouth, as well as the teeth of the anterior fragment and the anterior fragment itself. Thus anæsthesia of the posterior fragment and of the soft parts is all that is required. This result might undoubtedly be obtained by local anæsthesia, though the method is one which we have never employed. In one case we combined local and regional anæsthesia by direct action upon the mandibular nerve. With Sicard's able assistance the operation was successfully completed. The method is, however, only practicable in the case of very vigorous subjects. With this one exception we have always employed general anæsthesia.

Ether or chloroform? The abundant salivation almost invariably provoked by ether seems to us a definite contra-indication to its employment. For this reason we have always used chloroform, but even with this anæsthetic, the near presence of the anæsthetist constitutes a serious embarrassment. To reduce the inconvenience as far as possible we employ Ricard's old-fashioned apparatus, which obviates the necessity for constantly pouring chloroform on the compress. The anæsthetist is instructed to keep his hand and fingers well within the limits of the mask. By observing these precautions, the number of the possible channels of infection arising from the vicinity of the mouth and the anæsthetic manipulations is certainly reduced.

**Incision.**—The position of the incision is obviously dependent upon that of the fracture-site. We em-

ployed at first a rectilinear incision corresponding to the inferior border of the maxilla, but the method presented certain drawbacks, and we have since abandoned it. Sutures in this position are immediately over the plate and screws, a condition very unfavourable to good cicatrisation. Moreover, in spite of all precautions, the secretions from the mouth tend to soil the dressings. The further the incision is removed from the mouth, the better the chance of avoiding such a contingency. We prefer a curved incision (fig. 89), with the anterior extremity at the median line or the inferior border of the bone, and the posterior extremity at the angle of the jaw.

FIG. 89.—Diagram showing the usual position of the fragments; falling of the posterior fragment; extremities in irregular points. The figure shows the line of incision; curved and with the concavity uppermost; extending from the vicinity of the symphysis to that of the angle.

By this means a flap is raised which should be well freed to facilitate suture after operation.

Cicatrices should be avoided, especially those extending under the curve of the incision. We have occasionally seen complete mortification of the flap,

the circulation having been arrested by the cicatrix. The curved incision completes the anæmia, and the entire flap is thus deprived of nutrition. Where a cicatrix occupies this disadvantageous position, a band of healthy skin should be left intact between it and the incision in order to effectuate circulation.

**Exposure of the Fracture Site.**—The flap is raised by large strokes of the bistoury until the fracture site is well exposed. A thread is passed through it, the extremities of which are attached to a rather heavy forceps, which forms the counter-weight and acts as an automatic retractor (fig. 90).

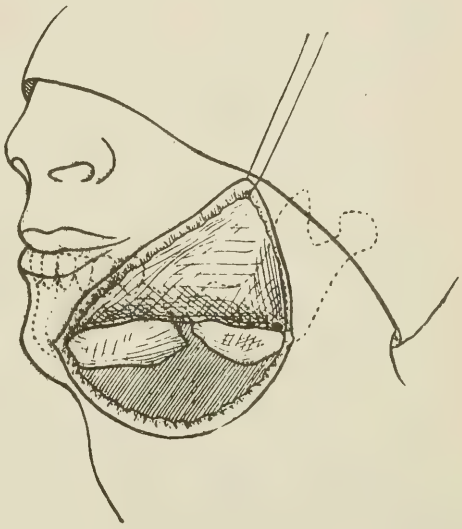


FIG. 90.—Diagram showing the flap turned back and the fracture site exposed.

Denudation of the fragments follows. A stroke of the bistoury, penetrating well down, is carried along the inferior border of the bone, and separation is effected by means of the scraper. It goes without saying that hæmorrhage is abundant. Unless the facial has been destroyed by the injury, it bleeds very freely. Moreover, regions which have formed the seat of prolonged inflammatory trouble remain very vascular.

The hæmorrhage is easily arrested ; we usually ligature only the facial.

The scraper should be employed for denudation of the fragments. As always, Farabeuf's curved scraper is a valuable instrument. It is advisable to begin with the posterior fragment, which is usually more easily decorticated. The external surface is first exposed, then the end of the fragment, which is usually pointed and irregular, and then the internal surface is denuded. Finally the superior border is exposed, taking care not to expose too much in order to avoid making a passage into the buccal cavity.

In the case of the anterior fragment, the inequalities of the external face are patiently followed with the tip of the scraper. The point, the internal face, and the superior border are all successively treated in the same manner. The anterior fragment after scraping rarely presents the neat and satisfactory appearance of the posterior fragment.

When the two fragments are denuded and an attempt is made to bring them together, it will be found that the fibrous obstruction by which they are separated has a pronounced tendency to interpose. This must be cut away with the scissors until nothing remains to hinder the contact of the fractured surfaces.

**Fresh cutting of the Fractured Surfaces.**—A further difficulty now presents itself. The surfaces of fragments are habitually irregular, and are usually pointed. Merely to cut away these surfaces would leave two bony points in contact. The sole method is to bring

down the point, and this must be executed with extreme discretion or the breach will be irretrievably widened. The removal of about 1 cm. should suffice.

With an electric lathe and some dentist's burrs the manœuvre is a simple one ; with the ordinary surgical outfit it is really difficult, and is usually imperfectly performed. In good hands, a burr such as that shown in fig. 91 gives rapid and satisfactory results. The arm of the electric lathe is of course covered with a piece of sterile linen, and the hand-piece and burrs are sterilised with the other instruments.

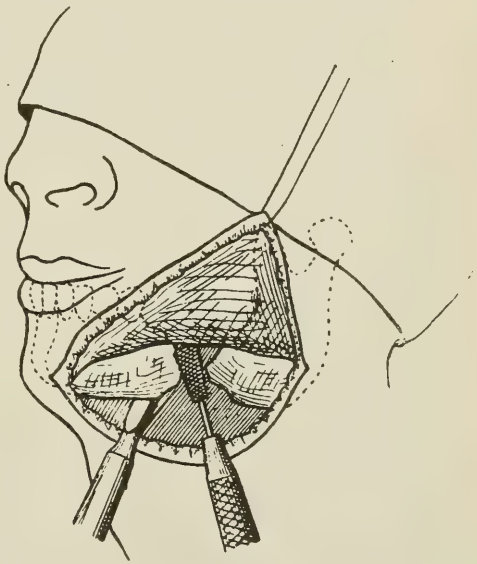


FIG. 91.—Diagram showing the manner of freshening the fractured surfaces by means of a burr on an electric lathe. The fragment to be cut is held with the curved scraper

**Application of the Plate.**—The plates which we prefer are of gilt German silver. It is true that they are not as resistant as Lambotte's plate, but the bone with which we have to deal is not uniform in its curve. It is almost flat in places, and becomes more convex as it approaches the median line. Hence a plate must be employed the curve of which may be modified by

means of strong pliers. After operation the mandible is immobilised by attachment to the upper jaw, hence the maintenance of reduction is not entirely thrown upon the plate, and its lack of absolute rigidity is not an insuperable drawback. It is usually fixed in place by means of four screws, two in front and two at the back. A point of paramount importance is to avoid the roots of the teeth. A root which has been injured by a screw may easily prove a source of infection to the fracture site. For this reason the plate is not applied to the centre of the external face of the fragments, but along their inferior border, the screws being inserted about 1 cm. above the edge. The precautionary measure of removing the marginal teeth still further limits the danger.

Before applying the plate the surgeon should assure himself that the two fragments may be easily brought together. Contact is essential, and an interval, though only of a millimetre, must almost inevitably compromise the results. Where there is difficulty in bringing the fragments together, a hole should be bored in each fragment, through which a strong wire is passed. The latter must permit of powerful traction, and must maintain contact until the plate is screwed into position.

These precautions having been taken, and the plate bent into shape with a pair of strong pliers, it is applied. A hole corresponding to the posterior screw-hole of the plate is bored in the posterior fragment. The hole is made with a burr on an electric lathe, its

size conforming to the diameter of the screw. The latter is immediately screwed into place. A hole corresponding to one of the anterior screws is bored in the anterior fragment and this is screwed into place. The application of the two remaining screws is a simple matter (fig. 92).

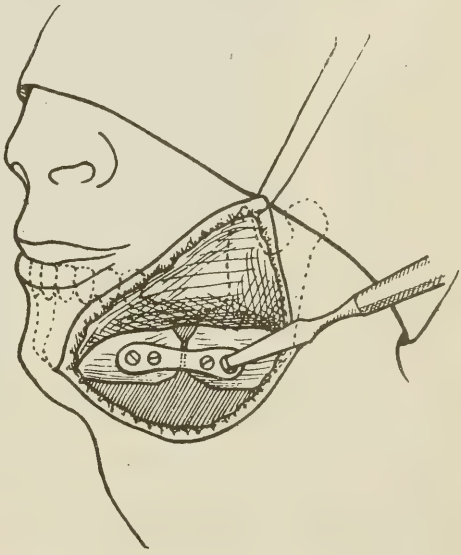
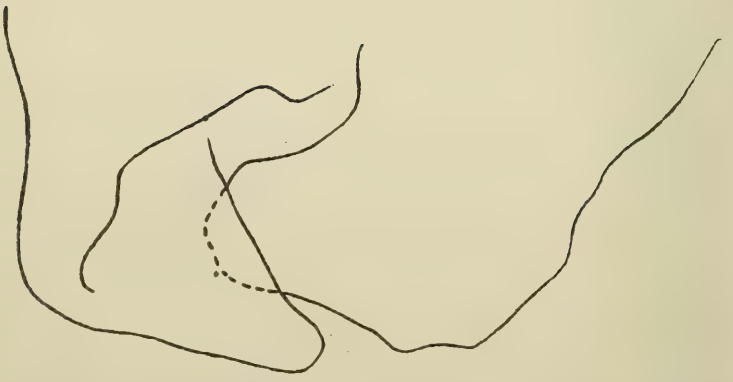


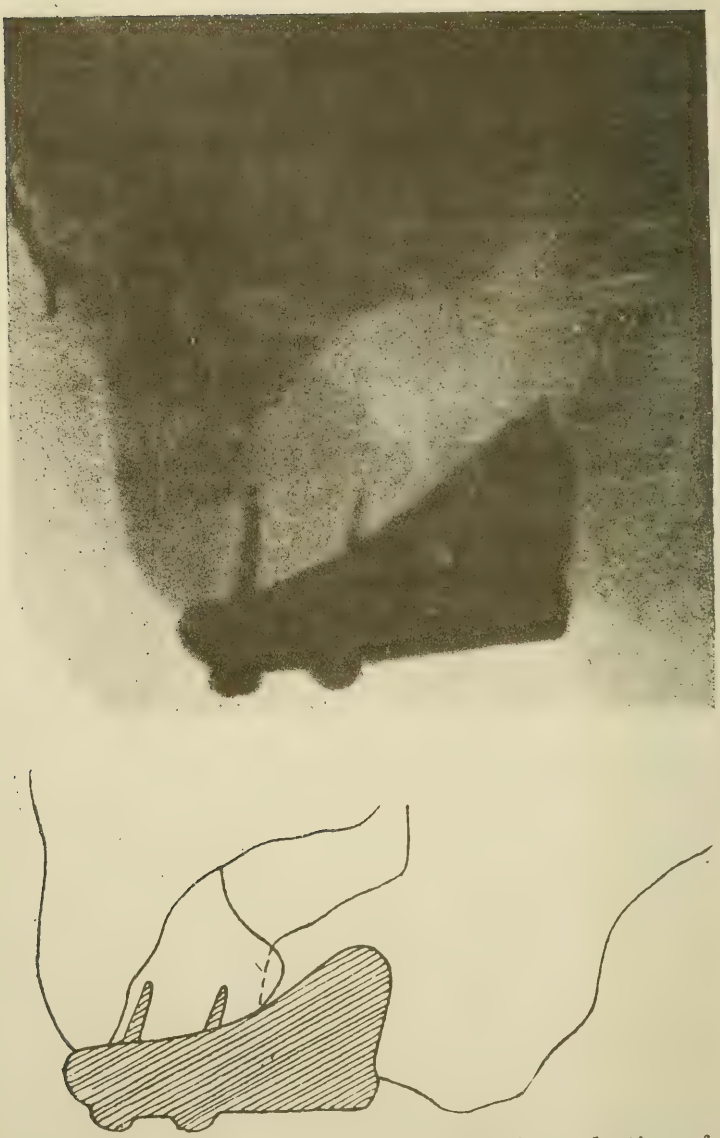
FIG. 92.—Diagram showing the plate attached by four screws, two upon each fragment.

One of the great difficulties associated with pseudo-arthrosis of the bones of the limbs is the poor consistency of the extremities of the bony fragments. Only too frequently the screws fail to bite, and their hold is very precarious. Occasionally their use is impossible and ligatures must be employed, always an unsatisfactory method. This complication does not arise in the case of the mandible. We have always found the bony extremities to consist of a compact and resistant tissue which gives the screws a good hold.

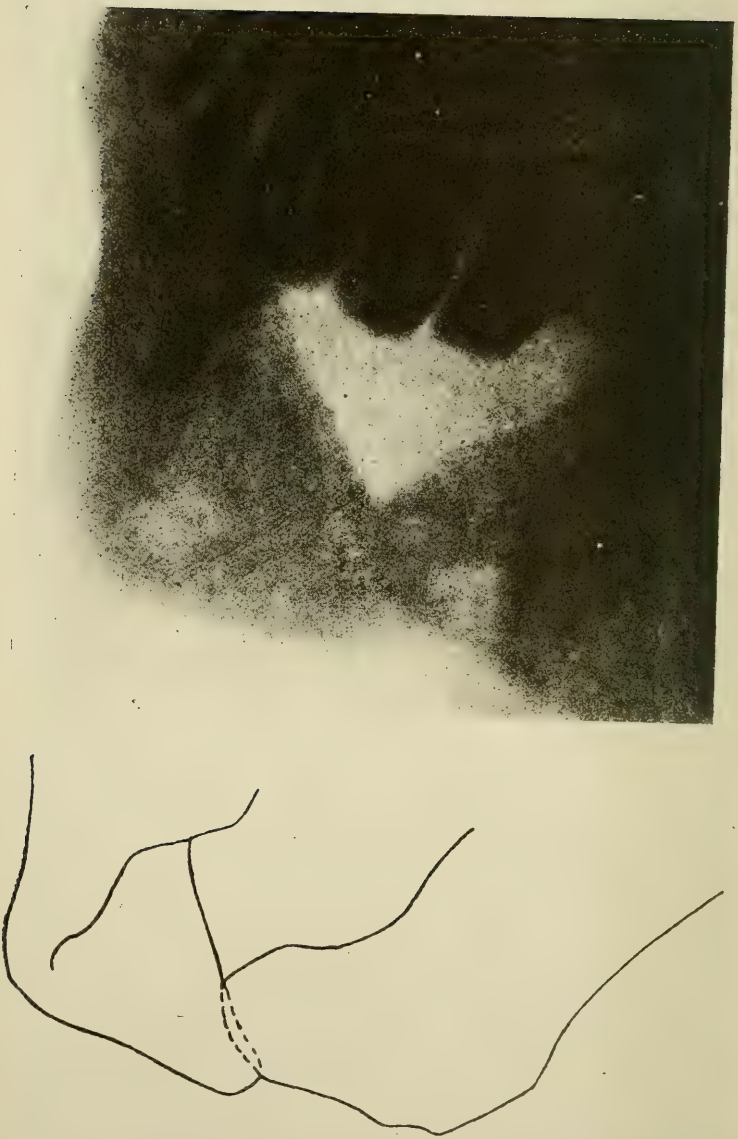
Once the four screws are in position, the operation is terminated. A gap corresponding to the inferior border of the bone, and due to the shape of the fractured extremities, is frequently observed. We have



Patient T. Skiagram and explanatory diagram. Pseudo-arthrosis of the mandible with loss of substance. Overriding of the fragments.



Patient T. Skiagram after osteo-synthesis; reduction of the fragments; application of a metal screw-plate. Skiagram and explanatory diagram.



Patient T. Skiagram after union and removal of the plate. Skiagram and explanatory diagram.

endeavoured to fill it with a chip taken from the posterior fragment, but we are not convinced that the results of this little operation are entirely satisfactory.

**Sutures.**—All that now remains is to put back the flap. Most frequently it is thin and traversed by cicatrices. Nevertheless it should be sutured along two planes, using catgut for the deeper plane, which brings the soft parts together, and silk or horsehair for the surface stitches. Unless the buccal cavity has been opened, drainage is not required.

This is the moment for dental intervention and the immobilisation of the teeth in occlusion. Two alignment wires with spurs having been previously attached to the upper and lower dental arches, to unite them at the end of operation by brass wire ligatures is a simple matter.

The wound is dressed with gauze kept in place by bands of adhesive plaster. The latter are arranged in such a way that they form a sort of barrier at the side of the mouth. Before coming round the patient is put in charge of a nurse, who sees that the dressings are not soiled by the buccal secretions.

### Results of Osteo-Synthesis

Up to the present we have had 18 cases under observation. Of these 7 were successful, 8 unsuccessful, and 3 are so recent that the results of operation are still uncertain. Those cases only are regarded as successful in which union is definitive. As in the case

of pseudo-arthroses of the limbs, failure is fairly frequent, but it must be borne in mind that in all our cases the pseudo-arthrosis was confirmed.

Union is very protracted, and this is in line with the observations of others of osteo-synthesis in fracture

FIG. 93.—Left lateral fracture ; pseudo-arthrosis in spite of prolonged immobilisation ; the skiagram shows the plate by means of which union is obtained.

of the long bones. Cases in which union is effected in two months may be regarded as exceptionally favourable. The average varies from three to four months, and we have known union delayed for five.

It is easy to judge of the progress made. We make a rule of removing the mechanism which effects occlusion at the end of two months. By that time the

screws have acquired sufficient play for it to be possible to judge whether mobility is still present. The apparatus is immediately replaced, and is removed every month for purposes of investigation.

In hospitals accustomed to the management of these

FIG. 94.—Left lateral fracture with large loss of substance; pseudo-arthrosis in spite of prolonged immobilisation; union by osteo-synthesis.

patients diet offers no difficulties. It should consist of liquid or semi-liquid foods; many patients are sufficiently adroit to manage minced meat.

Where infection is present we always remove the plate. We recommend removal of the plate in aseptic cases also, a course to which the greater number of patients consent. They are as anxious to rid them-

selves of this foreign body as if it were a fragment of projectile. Naturally, removal of the plate does not take place until after union, or until after proved failure at the end of five or six months.

Plates III, IV, and V show the position of the fragments in one of our cases before and after osteosynthesis, as well as their union after removal of the plate.

## II. Bony and Cartilaginous Grafts.[1] Actual Results

The question of the bony graft in connection with pseudo-arthrosis of all kinds is still in course of study.

We propose to describe definitive results only. If little is known of the ultimate outcome of bone-grafting in pseudo-arthrosis of the bones of the limbs, still less is known of its results in pseudo-arthrosis of the mandible. This is due, not to any inherent unsuitability of the method, but to the extreme scarcity of the literature of the subject. We shall describe, first, the results obtained by other surgeons, and second, the results which we ourselves have obtained.

. . . . .

Briefly stated, the situation is as follows :

The term " bone-grafting " has a certain biological significance which is comparatively definite and precise,

[1] Autografts are those taken from the subject; homografts those taken from another subject of the same species (man); heterografts those taken from a subject of different species (animal). We do not know of a specific term for grafts taken from the fracture site. They might very well be termed autografts *in situ*.

but from the surgical point of view this is not the case. Surgically, the graft is employed to fulfil a double purpose, and it is improbable that the conditions incidental to success are the same in both cases.

Sometimes the graft is employed as a simple agent

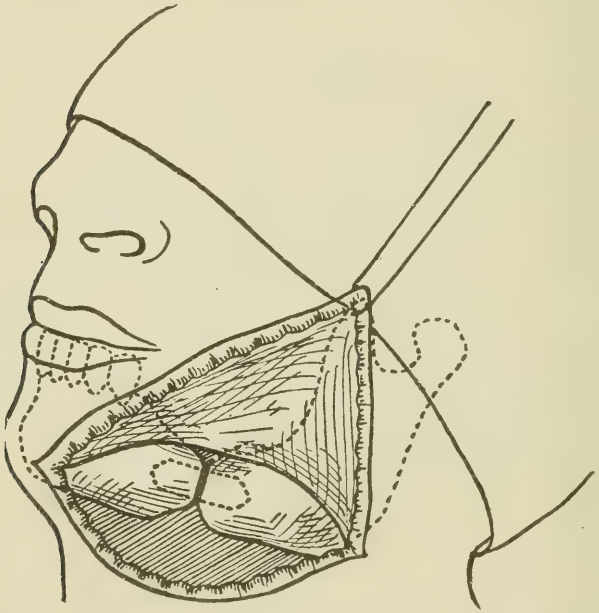


FIG. 95.—Bone graft. In this case the graft acts as an agent of union, the method being that of osteo-synthesis in which the metal plate is replaced by a segment of bone. The callus will be formed as in ordinary fracture by the two fragments, the graft will not take part in its constitution.

of union (fig. 95), when it plays the part of a bolt. In such a case the surfaces of the fragments are in contact and there is no loss of substance to be replaced. The typical indications for this use of the graft are supplied by fracture of the neck of the femur. Some surgeons introduce a long bony pin into the neck

with the object of immobilising the fragments and favouring union. The same method appears practicable in the case of the mandible, the graft taking the form sometimes of a pin and sometimes that of an osteo-synthetic plate attached, or even screwed, to both fragments. It is evident that success by these

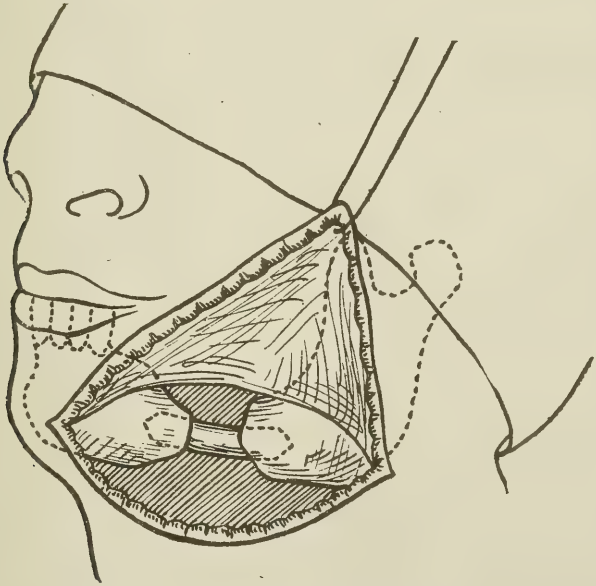


FIG. 96.—Bone graft. Here the graft does not act only as an agent of union. The space between the fragments is so considerable that union is not possible through their agency. The graft should take an active part in the formation of the callus. It is not certain that it will do so.

methods should be comparatively easy. There is no reason to doubt that a splint of this nature may effect immobilisation and ultimate union as well as or better than a metal plate.

Where the graft is intended to replace and to fulfil the functions of a missing portion of bone, the con-

ditions are entirely different. In the case of the first method it is a matter of indifference whether the transplanted fragment is eventually resorbed or not. Such is not the case here. The graft is expected not only to live, not only to preserve its essential qualities, and especially its solidity, but to participate actively in the processes of reparation and to play a structural part in the formation of the callus. In our view, no proof is forthcoming that such results may be anticipated with certainty, even in pseudo-arthroses of bones other than the mandible. The solution of the problem would be of inestimable value to the therapeutics of surgery.

That this point should be cleared up is essential, and it seems to us indispensable that all histories of cases should furnish very precise and explicit details in this direction.

. . . . .

There is yet another factor which appears to us to have a primary importance in its bearing upon the definitive results of bone-grafting.

Every one knows, and we have more than once recalled the fact, that a breach in the mandible of 2 cm., or even more, especially when situated anteriorly, may perfectly well unite without surgical intervention by the simple application of prosthetic mechanisms, or it may unite spontaneously. We have seen cases where union has been effected with a loss of 3 cm. and over.

The fact must not be lost sight of that, as the

majority of recent fractures unite without difficulty, the bony graft is indicated only in confirmed pseudo-arthrosis. Hence, except where loss of substance is very extensive, grafting should always be preceded by prolonged prosthetic treatment, and proof of the negative results of such treatment should be forthcoming.

It is superfluous to add that, the object of grafting being union, it cannot be regarded as successful unless union is obtained.

Histories of cases in which grafts have been employed should then elucidate two points: that a sufficiently long prosthetic treatment has been employed; and that there is clinical, and where necessary radiographic, proof of union.

. . . . . .

We have stated that osteo-synthesis does not necessarily fail when the wound becomes infected. Many surgeons have observed this fact in connection with pseudo-arthroses of the limbs; we can offer confirmatory evidence in regard to the mandible.

Does the same hold good in the case of the bony graft? We think not. There is no doubt that a transplanted fragment of bone may recover its vitality, provided that it acquires intimate contact with the tissues by which it is surrounded. But if it is bathed in pus, it seems to us that it must inevitably become a sequestrum. It is essential to the future of bone-grafting that this point should be cleared up, and we take this opportunity of appealing to those

of our confrères who have experience of the method, to publish detailed particulars of their findings in regard to this all-important matter.

. . . . .

Morestin has applied his general method of cartilaginous graft to mandibular pseudo-arthrosis. In a case described before the Société de Chirurgie (May 31st, 1916), the angle, together with the ramus, had been totally destroyed. The missing portion was replaced by a graft taken from the 6th and 7th costal cartilages. From the æsthetic point of view the result was perfect, but the union of the graft with the bone was incomplete, the graft continuing to present an obscure mobility. More recently other similar cases have been published by this author.

. . . . .

Morestin also proposed (*Soc. Anat.* 1902, p. 183) to treat pseudo-arthrosis of the mandible by the mobilisation of a bony bridge obtained from the posterior fragment, care being taken to preserve all the periosteal attachments. Unfortunately he has not been able to employ his method upon the living subject.

Cavalié (of Bordeaux) has employed a somewhat specialised technique in bone-grafting (*L'Odontologie*, June 30th, 1916).

According to whether the gap is more or less than 2 cm., he cuts from one or both fragments a bony strip, the length of which is greater than that of the space to be bridged. This bony strip is covered by its periosteum and by connective tissue; its lower face

is covered by spongy tissue. It is either pushed or turned backwards to the breach. From the author's description it seems better to leave a peduncle of periosteum. Where two grafts are employed, they are fastened together in the centre of the fracture site. The grafts are kept in place by a catgut suture.

Cavalié does not give a detailed description of his cases. He merely states that, in 15 cases out of 21, the grafts either united or were in process of union with the fragments.

Independently of any knowledge of Cavalié's researches, we have on several occasions made use of fragments detached from the fractured extremities. We must confess that our results were not entirely satisfactory. The *a priori* cause lies probably in the fact that the graft is insufficient to replace extensive loss of substance, and yet it is just this class of case with which the graft is required to deal.

At the Interallied Dental Congress, and before the Societe de Chirurgie, Sébileau gave an account of eight operations with bony grafts taken from the tibia. In only three cases has a sufficient period elapsed for results to be demonstrable. Of these, union was effected in one case, amelioration in the two others (see his communication to the Société de Chirurgie, November 8th, 1916). Interesting observations have also been published by Pont.

Delageniere has adopted a different method. His autografts are osteo-periosteal, and are obtained from

another part of the body. His observations were described before the Société de Chirurgie, May 3rd, 1916.

His method consists in taking a shaving of periosteum lined with more or less bony substance from the tibia. The method has been employed to replace loss of substance from the skull, the long bones, etc., and it has been applied to two cases of mandibular pseudo-arthrosis.

In one case pseudo-arthrosis was due to loss of substance from the body of the jaw. The two fragments were maintained in good position by means of a little metal plate with two holes. The interval of 15 mm. was filled by an osteo-periosteal graft from the tibia. In spite of somewhat profuse suppuration a voluminous bony callus was formed. At the time of publication the metal plate had not been removed.

The second case presented pseudo-arthrosis of the horizontal branch, with trapezoid loss of substance amounting to 2 cm. at the alveolar border and $3\frac{1}{2}$ cm. at the inferior border. An aluminium plate with two screws at the posterior end and one at the anterior end was applied. The osteo-periosteal graft was introduced under the plate between the two fragments. There were suppuration and expulsion by the mouth of the bony portion of the graft. The author states that new bone seemed to form.[1]

[1] Since these lines were written, Delagenière has announced that union has been effected in both his cases under satisfactory conditions. Other successful cases of his were described by Lebedinsky at the Interallied Dental Congress.

Our own researches have been conducted upon somewhat different lines.

Our first endeavour is to maintain the vitality of the graft, for it is certain that a bone completely detached from its connections may continue to live. With this object in view we have thought it preferable to perform the operation in two parts, with a long interval between them.

The first part of the operation consists in the removal of a fragment of bone, generally from one of the patient's ribs, and its introduction, with the minimum of operative manipulation, under the integuments of the region of operation in the vicinity of the pseudo-arthrosis. Simple puncture with the bistoury and separation of the soft parts are sufficient. The costal fragment is then slipped into the opening, which is closed with a stitch. The manœuvre is one of extreme simplicity. The graft is always tolerated, but our investigations do not permit us to conclude that it lives a normal life. In some of our cases a small secondary fistula, corresponding to a centre of necrosis of the graft, appeared after a few days. But this centre of necrosis was limited and was never accompanied by elimination. The greater number of cases healed by first intention.

As soon as the graft has, presumably, acquired means of nutrition, which is not until two or three months have elapsed, it is put into place by operation. In moving the fragment, its new vascular connections are interfered with as little as possible.

In only three cases were we able to accomplish the second part of the operation in a satisfactory manner. In the first case there was loose pseudo-arthrosis with loss of the entire left portion of the mandible including the ramus. With the object of achieving a physio-

FIG. 97.—Left lateral fracture with large loss of substance. Pseudo-arthrosis in spite of prolonged immobilisation. This case has been treated by means of a bone graft. Result as yet uncertain.

logical substitute for the temporo-mandibular joint, we grafted a bony fragment from the ribs together with the adjacent costal cartilage. The bony portion of the graft was secured to the extremity of the mandibular fragment by two screws. The result was excellent in the sense that union by first intention was

obtained. But to-day, eight months after the second operation, the graft is absolutely mobile on the mandible. There is no visible sign of a callus, and the functional gain is nil.

In a second case we adopted similar measures for a loss of substance of the left ramus measuring about 3 cm., which had been unsuccessfully treated for several months by means of mechanisms. We first introduced under the skin a costal fragment measuring about 5 cm. taken from the patient. The graft was tolerated. At the end of two months we moved the costal fragment and shaped each end to a point. These were inserted into two cavities cut in the mandibular fragments. The retention of the graft by this means was satisfactory. But the operation is of too recent a date for the definitive results to be apparent.

The third case is more recent still. A large part of the dental arch was missing. The graft was fixed by means of a metal plate screwed to the fragments in another place.[1]

. . . . .

In accordance with the suggestion of M. Lequeux, we have employed as grafts bones from a new-born infant. Through the kindness of the staff of La Maternité, Marseilles, we were able to obtain the body of a still-born infant under suitable conditions. We removed the principal bones of the skeleton and pre-

[1] These operations are now no longer recent. In no case was union obtained.

served them in vaseline in a refrigerator at + 4°. We found that fragments of these bones were perfectly tolerated in the tissues of patients not wounded in the face. We then decided to use them as true bony grafts in two cases of mandibular fracture. We followed the method of operation in two parts. The fragments were first introduced under the skin, where they were tolerated without ill effects. The one fragment consisted of the inferior extremity of the femur with the cartilaginous nucleus of growth, the other of the superior extremity of the humerus in the same condition. The future will show the value of these experiments.

To sum up : we believe we are justified in concluding that, at the present moment, the results of bone-grafting in mandibular pseudo-arthrosis are not as yet demonstrated. As Sébileau has said, they are encouraging—no more. It is to be expected, however, that the efforts made in many directions to obtain the cure of pseudo-arthrosis by bony transplantation will result in an improvement of general knowledge which must react to the benefit of mandibular lesion.

## CHAPTER VII

### ASSESSMENT OF THE DISABLEMENTS CONSEQUENT UPON FRACTURE OF THE MANDIBLE

In an article which appeared in the *Archives de médecine et de pharmacie militaires* (April 1916), we showed what we believe to be the best method of assessing incapacity arising out of mandibular fracture.

Briefly, compensation for disablement comes under five headings :

1. Discharge with pension.
2. Definitive discharge No. 1 with or without a grant.
3. Temporary discharge with or without a grant.
4. Return to an auxiliary branch of the service.
5. Return to active service.

The difference between definitive retirement No. 1 and temporary retirement No. 3 is appreciable only to the patient. In the case of the first, he can never again be taken for the army, his dismissal being definitive. In the case of the second, the patient's condition is assumed to be amenable to a degree of amelioration, which will render him liable at some future time for auxiliary or even for active service. Apart from incurability, a retirement pension pre-

supposes the existence of incapacity assessed at at least 60 per cent. Except where there is extensive loss of substance of the soft parts, fracture of the mandible, even with loss of bony substance, is not associated with so high a degree of functional incapacity. It follows that discharge with pension is granted only very occasionally. Nevertheless, the inclusion of this class in the scale of disabilities provides for certain isolated cases.

To the best of our knowledge, the degree of disablement which renders a man liable to be returned for auxiliary service is not fixed. There is a tendency to regard as eligible a maximum incapacity of 10 to 20 per cent.

With regard to grants, the military regulations have established a certain fixed scale which does not exist under civilian conditions. Disablements are calculated in tens per cent., and there is no recognition of intermediary figures.

We shall successively consider :

1. Loss of teeth, generally complicated by more or less important fracture of the alveolar border.

2. Fracture of the mandible, with its principal terminations, thus :

(*a*) Union in good position with preservation of occlusion.

(*b*) Union in malposition.

(*c*) Pseudo-arthrosis.

3. Closure of the jaws, so frequently associated with wounds of the face.

### I. Loss of Teeth, Complicated by Fracture of the Alveolar Border but without Complete Fracture

Loss of teeth is remedied by the employment of various prosthetic mechanisms, of which the best is the bridge. This is a fixed apparatus, the essential feature of which is a platform corresponding to the missing teeth and attached to at least two pillars. The pillars are metal caps, screw-crowns, etc., by which the teeth at each extremity of the dental breach are covered. This apparatus is cemented to the teeth, and it affords the nearest approach to the normal state. It is durable, and it completely re-establishes function.

Unfortunately the employment of the bridge is advisable only where the loss of teeth is minimal (four at the most). But wherever its employment is permissible we do not think that there are justifiable grounds for indemnity.

Larger gaps are filled by means of removable mechanisms, the base of which is composed of vulcanised india-rubber. These are fitted with good quality artificial teeth, and their attachment is by hooks of German silver. A partial apparatus of this kind, even of considerable size, perfectly re-establishes function so long as the remaining teeth assure a good anchorage; two sound teeth in each fragment, for example, a premolar on one side and molar on the other, are ample for the purpose providing they are

sufficiently apart. Here again we cannot admit any functional incapacity.

Where a complete apparatus is required, a judicial estimation of incapacity is dependent upon two entirely different factors. In the majority of cases these mechanisms are well tolerated and permit of almost normal mastication. But there are a certain number of patients who, through lack of perseverance, are unable to accustom themselves to the use of the apparatus. On the other hand, it must be remembered that the loss of all the teeth is not entirely the result of the traumatism. As a general rule the dental condition previous to injury was precarious, and for this the State cannot be responsible. We think that, on the grounds of intolerance, an indemnity is justified, but on account of loss of teeth we think that it should not be high. An average of 10 per cent. seems to us to be fair.

It is understood that the State bears the cost of replacing and repairing these mechanisms. For they are liable to wear out. The alveolar processes undergo involution, and an apparatus which was perfect at the time of its application may, after a certain time, become defective or break. The State might reasonably entrust this matter at a uniform tariff either to stomatologists appointed by the State, to the stomatological department of hospitals, or to dental schools.

## II. Fractures

These fractures terminate in various ways, all of which do not present disturbance of function in the same degree.

(*a*) *Fracture with union in good position.*—This does not require an indemnity, but the State undertakes to replace the teeth destroyed by the traumatism.

(*b*) *Fracture with union in malposition.*—Malocclusion should not be taken into account unless it affects at least half of the dental arch and is of such a nature that, whatever the position of the mandible, the patient is always unable to use the teeth of both sides simultaneously. This state is realised when deviation of half of the arch is so pronounced that its *ensemble* passes either within or without the corresponding teeth of the upper jaw. In such a case as this we estimate the incapacity at 20 per cent.

The infirmity is necessarily greater where the mandible is united but contracted, and closes entirely within the superior maxilla, the inferior teeth presenting no point of contact with the corresponding superior teeth. It is true that an attempt may be made to remedy this deformity by an apparatus attached in front of the remaining inferior teeth ; a supplementary dental arch, repeating the main arch and articulating with the superior teeth. It is obvious that the anchorage of an apparatus such as this will last only as long as the teeth are sound. Its stability and consequent utility disappear with them. In any case,

an apparatus of this kind is able to restore function only very imperfectly. Under such circumstances the indemnity should not be less than 30 per cent.

(*c*) *Fracture without union ; pseudo-arthrosis.*—Functional troubles arising from non-consolidation of fracture of the mandible are modified by the seat of fracture on the one hand and on the other by the degree of laxity of the pseudo-arthrosis—in other words, by the amount of substance lost.

A very loose pseudo-arthrosis with large loss of substance (a finger-width and over) should be largely indemnified. Wherever situated, it is accompanied by almost total suppression of function, and we estimate the indemnity at 40 per cent. We are aware that prosthetic apparatuses may be employed in cases of this class, but, owing to the extreme mobility of the fragments, such mechanisms are of minimal value. Their application does not appreciably lower the coefficient of incapacity, especially as their employment is dependent in part upon the dental conditions. As soon as the remaining teeth disappear, the functional value of the mechanism is reduced in a notable proportion which may fall to zero. There is one mechanism only which is able appreciably to re-establish function, and that is the bridge, extending as it does between the fragments and, by the agency of the teeth which serve as pillars, giving them solidarity. It is evident that such an apparatus is not applicable except where a sufficient number of teeth suitable for anchorage are present. In our view, two teeth on

each side of the gap is the minimum. In such a case the functional incapacity equals 20 per cent. But in view of the fact that the pillars of the bridge may fail and the patient be compelled to resort to a removable mechanism, we feel that the functional incapacity should not be estimated at less than 40 per cent.

Where the pseudo-arthrosis is less lax (a finger-width or two teeth and less), patients may under certain conditions almost entirely recover their functional capacity, though under others it remains considerably impaired. Here the coefficient of incapacity is indeterminate and ranges from 10 to 40 per cent.

Contrary to what one would suppose, the nearer the pseudo-arthrosis is situated to the temporo-mandibular joint, the less as a rule is the derangement of function. We were able to send a man back to the front who had lost a condyle with its neck as the result of fracture by a bullet. In these lesions, and in all those affecting the ramus as far down as the angle, there is no derangement of occlusion, and the movements of the mandible are unimpaired.

Where the pseudo-arthrosis is rather more forward and is situated in the molar region, it is almost invariably accompanied by deviation of the fragments, by which the articulation of the dental arches is destroyed. Here it is necessary for the patient to wear a guiding mechanism which will correct the deviation and restore normal occlusion. This is usually an easy matter, provided always that the patient possesses a certain number of sound teeth.

On the other hand, it must be admitted that even under these circumstances mastication is very imperfect. In consequence of the fracture of the mandible, which normally forms the rigid lever to which their action is directed, the power of the masticatory muscles is very much reduced. Such patients are practically incapable of chewing solid food and it is easy to foresee the troublesome sequelæ inevitable to imperfect mastication. In such circumstances, to estimate functional incapacity at 20 per cent. does not seem excessive. Where, however, the pseudo-arthrosis is narrower and tends to act as a fibrous callus, the indemnity may be reduced to 10 per cent. It is certain that the narrower the pseudo-arthrosis, the easier it is to provide a suitable mechanism, whether fixed or removable, and the more efficient the services which it is able to render. The question is one of degree, and can be decided only by careful examination of each patient.

It is in pseudo-arthrosis in the vicinity of the symphysis that prosthetic mechanisms attain their maximum of usefulness, for their chief function is to maintain normal occlusion by separating the fragments, which have an inherent tendency to approach one another. Experience shows that these apparatuses, having approximately equal points of support, provided in each case by half the dental arch and acted on by muscular synergic forces which are approximately equal, are more efficacious than lateral mechanisms. The bridge is particularly indicated in these pseudo-

arthroses with slight loss of substance, provided always that the points of anchorage are solid in character and sufficient in number (four teeth is the minimum).

Thus, in our view, median and paramedian pseudo-arthroses are those which, functionally speaking, are the least discouraging. An indemnity of 10 to 20 per cent. seems just. As we have shown in an earlier chapter, these cases are the least frequent.[1]

### III. Closure of the Jaws

Cases of mandibular constriction should be recommended for indemnity only under extreme reservation. Nevertheless it is regrettable, to say the least, that these cases should become permanent chronics in our special or general hospitals.

We have already had occasion to describe our experiences in this direction, which may be briefly summarised as follows :

It is certain that a proportion of these cases are those of pure simulation or of gross exaggeration. Proof is usually easy to obtain.

But we believe that the majority of closures are due to a simple muscular contraction. These are

[1] As we have shown, we do not believe that mandibular pseudo-arthrosis should be included among the cases eligible for pension with discharge. But the following must be regarded as incurable :

1. Pseudo-arthrosis resulting from very extensive loss of bony substance.

2. Pseudo-arthrosis which, having been operated upon either by osteo-synthesis or by grafting, has failed to unite.

These are the only classes of case where fracture of the mandible might possibly be compensated by discharge with pension.

cases of hypertonicity similar to those observed by neurologists. By employing an automatic mouth-opener (*ouvre-bouche*) and exercising moderate pressure, the resistance is found gradually to diminish in the same way that a tired muscle " gives," and the mouth may eventually be opened with ease. These patients should receive regular treatment continued over several weeks, and there is no question of indemnity.

Last of all, there are closures due to cicatrices, to muscular sclerosis, or to bony fusion. The first of these is undoubtedly amenable to surgical intervention. So also is the third, but it is rare. Out of more than 150 constructions arising from wounds of war, among which temporo-maxillary wounds were not infrequent, we have never seen a case. Fibrous retractions are very obstinate, and might in some cases provide grounds for indemnity. This is a matter which can only be decided, however, after surgical intervention. It is incontestable that section of the tendon of the temporal or operation of the Le Dentu is sometimes attended by good results. But this is by no means invariably the case, and some of our patients have relapsed in spite of every effort.

That absolute occlusion constitutes a serious condition seems to us incontestable, and an indemnity of 40 per cent. does not seem to us excessive. Such an instance has never come under our notice, and it must in any case be very exceptional.

Where the mouth may be opened as much as 2 cm. alimentation is perfectly possible.

In the very rare cases which occupy a place between absolute occlusion and an opening of 2 cm., we are of opinion that an indemnity of 10 to 20 per cent. should suffice. It must be repeated that such cases are quite exceptional.

Finally, we desire to emphasise the fact that our personal experience does not countenance definitive conclusions upon all these points. This brief summary does not pretend to do more than furnish a classification of the different types of disablement, such as may be employed as a basis of discussion.

# SECTION III

# FRACTURES OF THE ORBIT

# FRACTURES OF THE ORBIT

AND

# INJURIES TO THE EYE IN WAR

## *CHAPTER I*

## HISTORICAL

THE history of fractures of the orbit by projectiles of war obviously cannot be traced farther back than the use of gunpowder, but in the old writers are found interesting notes upon orbital traumatism in combatants of all ages.

HOMER, in the Fourth Book of the *Iliad*, tells us that "Penelius struck Ilioneus beneath the eyebrow towards the back of the eye, of which the pupil was torn away; and the spear, piercing the eye, came out at the back of the head; and Ilioneus, his hands stretched forth, fell."

Does this not clearly indicate an orbital fracture with cerebral lesion? . . . In the ancient books many similar indications are to be found.

It is not only among the poets that we can find much to interest us in this subject. Hippocrates gives wise counsel when he writes: "If it be needful to attempt the extraction of a foreign body deeply forced into the orbit through integuments and orbital muscles, only light traction should be used, and if the difficulties are great, it will be better to temporise." (HIPPOCRATES, *De morb. vulgar.*, Lib. V, Chap. XXI.)

When, in the wars of the middle ages, firearms appeared, injuries of the face and cranium multiplied.

In the writings of Italian surgeons of the period mention is made, in very imperfect manner, of fractures of the orbit, treated by the application of boiling oil.

It is not until we come to the sixteenth century, in ALBUCASIS, FABRICIUS of ACQUAPENDENTE, and especially AMBROSE PARÉ, that we find detailed descriptions of orbital lesions, accounts of the tolerance, sometimes very great, of these cavities with respect to projectiles, and of the necessity, in spite of everything, of hastening their extraction for fear of serious complications. The interference advocated by these surgeons was attempted by them whenever occasion presented; hence they designed a varied series of instruments, and the bullet extractors of RAVATON, PERET and BRAMBILLA remain as types of these instruments in medical literature.

In PERCY'S *Manuel de Chirurgié d'armée* (1792), a chapter headed "Wounds of the face, with foreign bodies," instructs us as to the state of knowledge of lesions of the orbit and of the eyes at this time; more particularly concerning affections of the walls of the orbit, with their effects on the neighbouring sinuses, frontal and maxillary. COLLIGNON and SCHMECKER have found pieces of iron and whole bullets which have remained *in situ* for many years and been finally eliminated by way of the nose. Curious cases of this kind are also to be found in the *Ephemerides*.

According to PERCY, not all the cases with a bullet in the eye were as fortunate as the one in which COVILLARD replaced the eyeball in the orbit, from which a foreign body had displaced it. "It is all over," said he, "with that organ, no matter how slightly a projectile has touched it. If it happened to be lodged in the fat at the back of the orbit we used one blade of our forceps and replaced the eye by COVILLARD'S method."

To show the gravity of such injuries, PERCY quotes two cases, one which came under his own observation, the other noted by STALPART VAN DER WIEL, of large

intra-orbital foreign bodies (points of swords or foils), which caused fractures of the roof of the orbit and in which extraction was followed by cerebral symptoms and rapid death.

In his *Manuel de Clinique chirurgicale*, published in 1832, LARREY devotes a chapter to wounds of the face by projectiles of war, and is the first to set forth original views on the mechanism, prognosis and treatment of these injuries.

The great surgeon of the First Empire, from his personal observation, cited cases of rapid recovery from orbital fractures, even when they presented a certain degree of gravity, and he remarks that the younger the subject the quicker the recovery.

On the other hand, he quotes two cases with cerebral complications and ultimate death from meningitis.

In the necropsies of these two cases, LARREY notes that as a sequence of the perforation of the orbit by the projectiles the bones had proliferated and so considerably reduced the volume of the cavities. He sees in this Nature's protective efforts to repair the damage caused by the shot. Intra-orbital foreign bodies, he adds, are sometimes tolerated for very long periods, and then evacuation takes place, sometimes by the mouth, sometimes by the nasal fossæ.

BAUDENS, in 1836, and VALLÉE, in 1838, collect the cases previously published, the first in the form of clinical lectures, the second in his inaugural thesis. We do not, however, find in these works anything to merit prolonged consideration.

More important and instructive is the article published in 1851 by BERTHERAND entitled "Des plaies d'armes à feu de l'orbite" (Gunshot wounds of the orbit). "If a shot," he writes, "strikes the eye, the spherical elastic surface which it presents may cause the ball to deviate; or it may happen that the eye, without being ruptured, may be forced outside the cavity. Deflected by the globe, the projectile may retain sufficient force to fracture the bony walls of the orbit and lodge in adjoining cavities (sinuses,

nasal fossæ, cranium). The resistance of the bones which form the anterior margin of the orbit and the convexity of the superciliary arch explain the deviation of gun-shots and the comminuted fractures which result when they strike these parts. It is superfluous to emphasise the gravity of the injuries due to the frequent penetration of projectiles into the cranial cavity" (*Annales d'Oculistique,* 1851, p. 127).

DUPUYTREN, and after him DESMARRES, give a classification of orbitral fractures (1854). They distinguish: 1st. Fracture of the margin (DUPUYTREN and BAUDENS); 2nd. Fracture of the walls (DUPUYTREN and HENNEN), extending sometimes to the apex of the orbit; 3rd. Fractures of the apex, almost always complicated by visual disturbances, because of injury to the optic nerve; 4th. Fractures by "contre-coup," from traumatism of the cranial bones or of the bones of the face.

A similar classification, as regards intra-orbital foreign bodies, is given by DEMARQUAY in his "Mémoire sur les corps étrangers arrêtés dans l'orbite" (An account of cases of foreign bodies lodged in the orbit) (*Union médicale,* 2nd series, Vol. IV, 1859). DEMARQUAY, making use of cases reported by DEMOURS, DESMARRES, GENSOUL, WALDON, CUNIER, JOEGER, divides them into: 1st, projectiles propelled by gunpowder—shot, particles of lead, other fragments; 2nd, portions of perforating instruments; 3rd, fragments of glass; 4th. pieces of wood. He describes with precision the concomitant symptoms: sub-conjunctival ecchymosis, hæmorrhage from nose and mouth, and insists upon the exophthalmos produced by a collection of blood or pus. Orbital inflammations are not frequent in gunshot wounds, he says, because of the relative asepsis due to the heating of the foreign body. We should certainly emphasise the correctness of this remark; orbital abscess following gunshot injuries has become more and more infrequent with the improvements in modern ballistics and the great initial velocity of projectiles. DEMARQUAY further draws

our attention to the cerebral injuries which may remain long in a latent condition and suddenly cause the death of the patient from cerebral abscess.

Although PERCY advises enucleation of the eyeball to facilitate the extraction of the offending foreign body, DEMARQUAY, and with him WARLOMONT and TESTELIN, find this procedure too energetic, and very prudently recommend keeping the eye so long as vision remains.

In the following years there is but little mention of fractures of the orbit. However, in 1862 DEVAL, DICKSON, and in 1865 MACKENZIE, mention some observations on foreign bodies tolerated during long periods (from three months to seventeen years). Later comes BERLIN, who, in an essay well provided with references to authorities, clearly sets forth the matter.

From this work we extract the details which appear to us of importance. Should the projectile, says the writer, strike the temporal region obliquely the eye may be torn away. If it penetrate horizontally, traversing both orbits, section of both optic nerves follows (Thompson's case). Injuries of the lower wall, rarer than the others, smash up the orbital floor and the maxillary sinus. In some cases the projectile exhausts its penetrative power on the bones of the face and comes to rest against the roof of the orbit.

In fractures of the superior wall there is often an accompanying cerebral lesion. Recovery is frequently due to the facility with which the wound gets rid of its discharges, if the orbital margin is involved in the loss of substance (16 cases out of 19). In fractures of the vault alone prognosis is graver (41 deaths in 55 cases). Frequently death is sudden from hæmorrhage; or, on the other hand, delayed, from encephalomeningitis. Diagnosis of the seat of fracture is therefore of great importance, and BERLIN advises, what would be wrong otherwise, exploration of the injury by means of a probe. He enlarges next on fractures of the optic foramen with secondary lesions of the nerve, due either to compression or to the

tearing of the nerve-elements, brought about by splinters or by effusion of blood into the sheaths. He describes at length the ophthalmoscopic appearances in those disorders which lead to white atrophy. As to the treatment of orbital fractures, BERLIN recommends the removal of the bony fragments of the vault and the establishment of as perfect a system of drainage as possible, and advises recourse to enucleation only when vision is irremediably compromised.

MANZ (1867), SCHABERS (1872), and LEGOUEST (1873) confirm the facts demonstrated by BERLIN.

According to GALEZOWSKI (1875), fractures of the orbital margin are not very frequent. Most often mentioned are fractures of the internal angle, particularly of the lacrymal bone, and fractures at the apex with damage to the optic nerve. He quotes the classic case of NÉLATON (punctured wound with umbrella, fracturing the roof) and that of BORSA (foreign body in the orbit tolerated twenty-four years, extracted with success).

DE WECKER and LANDOLT (*Treatise on Diseases of the Eyes*, Vol. IV, p. 784, 1889) divide fractures of the orbit into direct and indirect, the first provoking exophthalmos, the projection of the eye forwards, and actual dislocation. They describe minutely the affections of the different walls and conclude by condemning probing of the wound owing to fear of introducing infectious germs from the orbital cavity into the cranium.

They emphasise the fact that the absence of every symptom on the side of the general condition, and of the cerebro-spinal axis in particular, does not imply a benign injury, for cerebral affections, often latent, may blaze out suddenly and lead to a fatal issue in a few hours.

DELORME, in his very remarkable *Traité pratique de Chirurgie d'armée* (1890), also reviews the various forms which have been discovered by clinical observation; his chapter is an accurate *résumé* of the knowledge available at that date.

We are indebted for information, unpublished from the point of view of statistics, to CHAUVEL (article "Orbite," *Dictionnaire des Sciences médicales*) and to CHAUVEL and NIMIER in their work on Military Surgery published in 1890. These authors have ascertained that fractures of the orbit, as frequent in 1870 as those of the cranium, have caused, as in previous wars, a much lighter mortality than the latter (6·9 per cent. instead of 21·7 per cent.). In the Crimea, the difference amongst our soldiers was less pronounced (18·5 per cent. instead of 28 per cent.); whilst during the campaign of 1866, the deaths following wounds of the face were five times less numerous than the losses from cranial lesions (3·9 instead of 21·7 per cent.); in Tonquin the difference is still more marked (4·44 per cent. against 25·28 per cent.).

Fractures of the orbit with ocular complications are relatively frequent, which is doubtless due to the slight resistance of the tissues of the eye, and also to its situation in a bony cavity, fractures of which affect the organ which it contains. The proportion of injuries of the eye to wounds in general is: 0·5 per cent. (America), 0·81 per cent (1870–1871)—a relation which in the Crimea rose to 1·75 per cent., and in the Russo-Turkish war (1877–1878) to 2·5 or 3 per cent. Relatively to injuries to the head, out of 100 some 5·5 can be reckoned (America, War of Secession); 7·7 (Denmark); 8·5 (1870–1871); and in the wars of the Crimea and the Caucasus the proportion was 11·3 and 18 per cent. Finally, out of 100 ocular lesions in the German Report of 1870, there are 47·6 of the left eye, 40·3 of the right eye, and 9·7 of both eyes. These statistics have further established that, following injuries of the orbit, the eyeball was destroyed in only 39·4 per cent. of the cases, and that small missiles caused the loss of the organ more often than large, which penetrate less readily into the orbital cavity. While on the subject of these statistics, and to complete them, we quote the following details :—

(*a*) *Injuries of the orbit with preservation of the eye* :—

1870–1871. German Report, 37·6 per cent.; CHENU, 51·6 per cent. of cases wounded by large projectiles.

(*b*) *Injuries followed by destruction of the eye* :—

1870–1871. German Report, 62·4 per cent.; CHENU, 73·5 per cent. by small projectiles.

1870–1871. German Report, 35·9 per cent.; CHENU, 48·4 per cent. by large projectiles.

OTIS, in the War of Secession, gives 1190 cases of orbital gunshot injuries, of which 63 resulted in blindness of both eyes, and 725 in loss of vision of one eye. He adds 51 cases of injuries with disorder more or less marked of the visual function, and 256 indeterminate cases. The mortality was considerable in the first category, 17 out of 63; and in the second series 57 out of 725, owing to cerebral complications or lesions of the greater vascular trunks. Sympathetic ophthalmia appeared very frequently, but OTIS gives no information on this subject.

Besides articles by SCHMIDT (1873), by PANAS (*Traité des Maladies des Yeux*, 1874), by GOLDZIEHER (*Gunshot Injuries of the Orbit, and sequent visual disorders*, 1877), we find a very complete account by DELENS (in *Duplay et Reclus*, Vol. IV, p. 508). According to DELENS, who has judiciously weighed the previous literature on the subject, when the different points of the base of the orbit are struck by a bullet, the resulting injuries are rarely limited to the bony margin, and present great variety. Extension of the fracture to one of the walls of the cavity is very frequent; it is especially so when the superior wall is involved, and in this region assumes a peculiar gravity, because of the proximity of, and possible damage to, the brain, which is sometimes laid bare. Fractures of the external wall are the most frequent; if the projectile does not completely traverse the orbital cavity fracture of the external wall displaces the globe inwards and forwards, without directly

injuring it. But most frequently, especially with the penetrating force of modern projectiles, the bullet continues its path, fractures the internal wall, and if its direction be transverse, breaks both walls of the orbit on the opposite side, emerging through the temporal fossa. In this course the brain is often injured at the same time as the visual apparatus. One has seen, rarely it is true, both optic nerves simultaneously divided. Fractures of the internal wall, by reason of the proximity of the nasal fossæ and nasal canal, give rise to two almost constant signs, epistaxis and emphysema. Fractures of the inferior wall are accompanied by injury to the maxillary antrum. Should the intra-orbital nerve have been injured, blepharospasm or anæsthesia of the cheek occur. Under other circumstances, the fracture is followed by a falling in of the eyeball, which is displaced into the antrum (cases of Massot, Magel, and Langenbeck). If the roof of the orbit is involved, the traumatism is almost always accompanied by loss of consciousness, paralyses, convulsions and coma. These lesions are of peculiar seriousness, but difficult at times of diagnosis, nerve phenomena being the sole symptoms which would cause their presence to be suspected. The wound must not be probed, and if the foreign body is still lodged in it attempts at extraction are often more dangerous than abstention.

In the period which extends from the commencement of the twentieth century to the beginning of the war there is no comprehensive work dealing with the subject. Some cases are recorded, amongst which we may mention those of Coppez (1899), fracture of the orbital vault with contusion of the globe and traumatic intra-orbital adhesion of the levator palpebræ and superior rectus; of Laroyenne and Moreau (1907), three cases of cranial fracture complicated with probable fracture of the optic foramen; of Nievolina (1908), a case of gunshot wound of the orbit.

It remains to point out and recommend the two

very complete articles by ROHMER and ROLLET, which will be found *in extenso* in the *Encyclopédie française d'Ophtalmologie.*

ROHMER, after having explained the mechanism of the affections of the bony walls of the orbital cavity, describes the various ocular complications which may arise in consequence. He relates cases of amaurosis after contusion of the orbital margin—amaurosis which the ancients attributed to reflex action, and which PANAS and ABADIE set down to effusion of blood in the sheaths. DELORME, who reports several such cases from the war of 1870–1871, has found hyperæmia of the optic disc and the appearance of peri-papillary pigment deposits. This amaurosis may be transitory, or may result in white atrophy of the optic nerve. ROHMER then enlarges on the intra-orbital effusions of blood so frequently found; upon the cellulitis, which is, on the other hand, so rare, but of grave import if it accompanies a fracture of the vault; upon acute œdema of the adipose tissue (NIMIER); upon injuries to the optic nerve (neuritis, atrophy, avulsion, etc.); and finally upon injuries to the motor nerves and muscles of the eye (WOHL, BERTHOLD, CHAUVEL and NIMIER'S cases).

ROLLET, in the same encyclopædia (Vol. VIII, p. 374), studies in the first chapter the indirect fractures of the orbit caused by a fracture, either of the skull-cap or of the base of the skull, the mechanism of which has been elucidated by the experiments of ARAN, FELIZET, BRAQUEHAYE, CHIPAULT and others, dealing with fractures by radiation, contre-coup, or smashing in. He next describes direct injuries and passes in review the different varieties of osseous lesions of the walls. The copious list of authorities attached to this article has enabled the author to set forth, as well as possible considering the few documents to hand, the symptomatology, prognosis and treatment of these orbital lesions. ROLLET has investigated all the cases previously published by clinicians; and those interested in the question will find in this article

a complete bibliography which the nature of our work will not permit us to reproduce here.

A recent thesis, written at our instigation, should be noticed. It is by Dr. Antonio de Menacho, and is entitled, "*Heridas orbito-oculares en cirurgia de guerra.*" (Thesis, Madrid, 1916.)

The principal object of this historical sketch is to prepare the reader for comparing what has been observed by military surgeons in former wars with what we see in the war to-day.

## *CHAPTER II*

# THE ORBITAL CAVITY

### Its Conformation, its Protective Rôle, its Resistance to Traumatism, its Vulnerability

The bones of the face and cranium in uniting one with another form several cavities, the most important of which is the orbital cavity, destined to lodge the eyeball, the muscles which move it, the vessels and nerves which animate it, and the cellulo-adipose tissue which surrounds and supports it.

### Conformation

The orbital cavity has the form of a quadrangular pyramid, the antero-posterior axis of which is directed obliquely from before backwards and from without inwards. This comparison of the orbit with a pyramid, although classic, is far from being rigorously correct, for two reasons. First, the widest part does not correspond to the margin of the orbit, but is about a centimetre behind (Fig. 1). Second, the edges of this quadrangular pyramid are so slightly marked that the orbit really resembles a cone. The cast of the orbital cavity shows, in fact, that its walls are gently rounded; indeed, that the comparison of the orbit with a conical cavity is certainly the most correct that can be made. If, following the classics, we still give to it a pyramidal form, it is because it is more convenient for purposes of description to speak of a base, an apex, four surfaces and four margins.

We shall adhere to this division, artificial though it

may appear, and shall describe successively the base, apex, the surfaces and the margins of the orbital cavity.

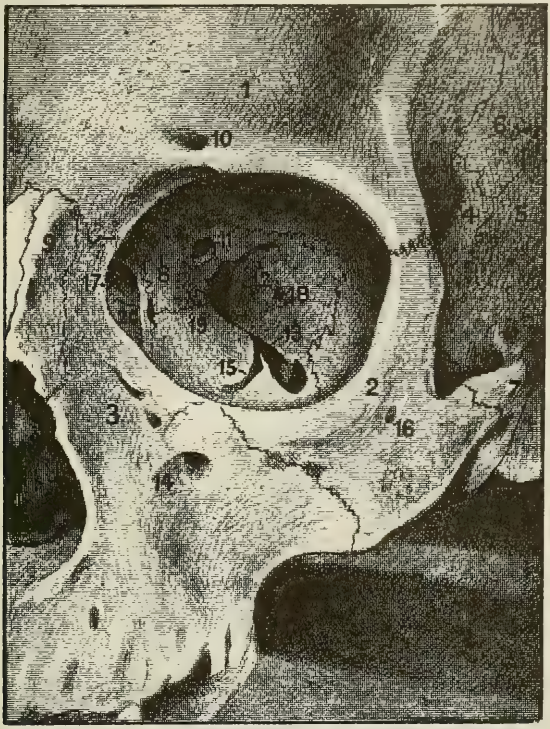



FIG. 1. *Bones of the Orbit.*—1. Frontal bone. 2. Malar bone. 3. Superior maxilla. 4. Superior portion of the great wing of the sphenoid. 5. Squamous portion of the temporal bone. 6. Anterior-inferior angle of the parietal bone. 7. Mastoid process. 8. Os planum of ethmoid. 9. Nasal bone. 10. Supra-orbital foramen. 11. Optic foramen. 12. Sphenoidal fissure. 13. Spheno-maxillary fissure. 14. Infra-orbital foramen. 15. Infra-orbital groove. 16. Foramen for malar nerve. 17. Lacrymal groove. 18. Lesser wing of sphenoid. 19. Orbital process of palate bone. 20. Lacrymal bone, os unguis.

*Base.*—The base of the orbit, circumscribed by the orbital margin, has the form of a quadrilateral with rounded angles. It is narrower than the cavity itself,

so much so that a solidified cast of the orbit cannot be withdrawn intact without breaking the bones.

The circumference of the orbit is formed above by the supra-orbital arch of the frontal bone, on each side by the angular processes, internal and external, of the same bone; internally and below, by the nasal process of the superior maxilla; externally and above, by the antero-posterior margin of the malar bone.

In passing the finger over the orbital margin several points are met with which merit special mention. Notice in the first place the supra-orbital notch or foramen (*incisura supra-orbitalis*), quite recognisable through the skin. This orifice is situated usually twenty-five millimetres from the median line. Very often to the inner side of the supra-orbital notch is to be found a small notch called the *incisura frontalis* (MERKEL). Outside this supra-orbital notch one notes that the orbital margin becomes particularly strong, prominent and resistant.

*Apex.*—The apex of the orbit corresponds to the most internal and widest portion of the sphenoidal fissure. This fissure is situated along the internal border of the great wings, and is the space between this border and the inferior surface of the lesser wings. The fissure, whose outline somewhat resembles that of a club, is wide internally and narrow externally, where it tapers off and is lost under the processes of Ingrassias (the lesser wings). The sphenoidal fissure transmits the third and fourth nerves, the ophthalmic branch of the trigeminal, the sixth nerve, the ophthalmic vein, a prolongation of the dura mater, and an arteriole, a branch of the middle meningeal. To the internal margin of the fissure is attached the ring of Zinn, inserted into a small bony tubercle, more or less developed according to the subject.

*Walls and Surface.*—The walls of the orbit are four in number: superior, inferior, external, internal.

The superior wall or roof is formed by two bones; the orbital plate of the frontal and the inferior surface of the lesser wing of the sphenoid. It takes the form

of a cupola, especially in its anterior part, by reason of the orbital margin which overhangs and tends to make the bend of the arch seem deeper.

In examining this superior wall of the orbit, there are to be seen: in front and externally, the lacrymal fossa in which is lodged the gland of the same name, behind this the suture of the frontal with the lesser wing of the sphenoid, externally that which unites the frontal with the great wing of the sphenoid; internally, that which joins the same bone with the paper-like os planum of the ethmoid. These sutures are quite invisible in the orbit when covered with periosteum.

The superior wall of the orbit is remarkable for its thinness; upon the dry bone, when the light passes through from above, the digital impressions of the anterior cerebral cavity can be readily seen. It should be noticed, however, that in the internal portion, in the adult, and still more in the aged, this surface is covered to a greater or less extent, by the frontal sinus, which is sometimes very large.

The inferior wall or floor is formed by the superior surface of the pyramid of the superior maxillary bone (the orbital process) and by the superior surface of the orbital process of the malar bone; posteriorly is to be seen the little orbital facet of the palate bone. This wall is smooth and regular, its highest portion is towards the inner side; thence the surface inclines forwards and laterally; it is slightly concave on the whole, but this concavity is not well marked; it may even give place to a certain amount of convexity, due to the maxillary antrum, which, like the frontal sinus, may attain excessive dimensions and become distended, and so in a manner raise the wall which separates it from the orbit.

Besides the sutures which unite the superior maxilla, the malar, and the palate bone, on the floor of the orbit is seen the intra-orbital groove, which, after a course averaging two centimetres, becomes a complete canal, the intra-orbital canal. The length of the groove in proportion to that of the canal varies in

different subjects; before it is roofed in by a plate of bone, the groove is changed into a canal by a fibrous membrane which is continuous with the periosteum of the orbit.

When the inferior wall of the orbit is examined on the living or dead subject the nerve is visible as a whitish cord, owing to the transparency of the periosteum.

The external wall is formed by three bones: the great wing of the sphenoid, the orbital process of the malar bone, and the most external portion of the orbital plate of the frontal bone.

The portion of this surface which belongs to the sphenoid is limited by the sphenoidal and the spheno-maxillary fissures; at this level the wall is flat; in front it is a little rounded; everywhere it is smooth, except in the vicinity of the sphenoidal fissure; quite at the posterior part there is a bony projection in the form of a spine, which serves for insertion of a portion of the external rectus (the lower head).

The sutures on this surface which unite the three bones, the malar, frontal, and sphenoid, have the form of a T, the horizontal branch of which extends from the outer extremity of the sphenoidal fissure to the external and superior angle of the base of the orbit, while the vertical branch, separating the malar bone from the great wing of the sphenoid, reaches the anterior extremity of the spheno-maxillary fissure. Further, on this surface must be noted the malar canal, which, commencing on the superior surface of the orbital process of the malar bone, bifurcates in the interior of the bone to open both on the internal and external surfaces; these two canals give passage to nerve filaments of the orbital branch of the superior maxillary nerve.

We will cut short this description, which must of necessity be brief; it will suffice if the reader, to grasp what follows, will carefully examine Fig. 1.

### The Protective Rôle of the Orbit

Just as the cervical and dorsal vertebræ protect the spinal cord and the lumbar vertebræ the cauda equina, in the same manner the cranial vertebræ protect the encephalon and those advanced portions of the nervous system which are the sensory nerves, notably the optic nerve and the retina.

We are not concerned with taking sides for or against the vertebral theory of the cranium, we are quite aware that it is a much-discussed question, but we cannot forget that certain anatomist philosophers (Goethe, Oken) have not hesitated to describe four cranial vertebræ, and to find in each of them the constituent portions of a typical vertebra—a vertebral body, two vertebral arches and a spinous process. Those who accept these vertebræ classify them thus: Occipital, spheno-parietal, frontal and nasal; it is the third, the spheno-frontal vertebra, which interests us; its body is represented by the body of the anterior sphenoid, its foramen by the ethmoid notch, its laminæ by the lesser wings of the sphenoid and the frontal bone: it is this which forms the orbital chamber for the protection of the retina.

Grave objections have been brought against this theory. It is certain that the cranial bones have a special evolution; the base of the cranium comes from the endoskeleton, the cartilaginous skeleton, while the vault comes from the exoskeleton, the dermic skeleton; besides, above the basilar process, the notochord is no longer present, and *no notochord, no vertebræ*. Finally, in the cranium a phenomenon constant in the vertebral column is absent, viz. the appearance of small cubical masses separated by transverse lines, called protovertebræ. The cranium has no protovertebræ. However, these objections have not prevented Kölliker from accepting the vertebral theory of the cranium, relying upon the presence of certain swellings in the cephalic portion of the notochord, and upon the presence during fœtal life

of intervertebral discs; one of the most anterior of these discs, the third, is between the body of the anterior sphenoid and the posterior sphenoid. It belongs to the vertebra which surrounds and protects the eye.

Admitting that the vertebral theory of the cranium, properly so called, is no longer acceptable, there remains what is termed the segmental theory of the cranium (HERTWIG), which consists in supposing that the head of the vertebræ is the anterior prolongation of the trunk, and that, like the latter, it is composed of metameres (*Cephalic metamery*), in each of which three elements should be found—a mesodermic segment, a skeletal segment, and a nervous segment. It is evident that the cephalic metamery is much more complicated than that of the trunk, because the metameres of the head are sometimes divided into two, sometimes blended, and the different segments, mesodermic, skeletal and nervous, atrophy or develop according to the necessary adaptations of the organism.

Whatever share of scientific truth may be comprised in these different theories, it is none the less true that the fragment of brain which we term the optic nerve (commissural nerve), and the retina (cortical substance) find, in what the partisans of the vertebral theory of the cranium call the third vertebra, an efficient protection against traumatism. The box of bone which, like a substantial coffer containing a precious treasure, guards the cerebro-spinal axis is widely open at the level of the eye, because it is necessary that the eye should search the space in front of it; but behind and on every side, this box is solid and efficacious as a protective mechanism. Let us see by what fortunate arrangements it is enabled to resist injury.

## Resistance to Injury

It will be convenient to consider successively the base of the cavity and its four walls.

*Resistance of the Base.*—The base of the orbital cavity is built up, as we have seen, by the frontal, malar, and superior maxillary bones. These are three bones of great resisting power; a violent blow will be needed to fracture them, and in the mechanism by which they are locked together we again find conditions which add to the solidity they already possess from their thickness and the compactness of their substance.

In fact, it is evident that a traumatism, affecting the upper portion of the orbit at the level of the orbital arch, will be immediately communicated to the two pillars represented by the internal orbital and the external orbital processes of the frontal bone; the malar bone, so firmly locked into the facial foundation, and the superior maxilla, by means of its highly resistant upper portion, receive the shock. The vibrations produced by the blow of a blunt instrument will be spread over the bones of the face. In the same manner, the shock of the stroke of a hammer, handled by a giant, falling on the dome of a cathedral would be lost in the ground. If it is suggested further that the vault of the orbital arch is a vault like a basket-handle of the Roman type it will be seen how difficult it is to break it.

Should the blow strike the inferior orbital arch, the same conditions of resistance will be found. There again it is a question of an arch and a vault, and the blow, falling on the superior border of the maxilla or the horizontal ramus of the malar bone, will be propagated in the inverse direction to that of the shock to the superior arch, but under the same general conditions. The two orbital processes of the frontal bone in this case form the pillars; and the Roman vault, here as in the superior arch of the orbit, efficiently resists violent blows. When the injury affects the superior part of the orbit, its power will be dispersed in the facial mass; when it concerns the inferior part, the vibrations it sets up in the bones are lost in the cranial mass.

Finally, when a blow from a blunt instrument

strikes directly the external wall of the orbit, the malar bone itself, it meets a particularly efficacious resistance; for outside the pillars which receive the shock, and which are in this case the superior maxillary and the external process of the frontal, we find the zygomatic arch, which is quite comparable with the flying arches by means of which architects strengthen Gothic cathedrals. The crushing in of such a vault is particularly difficult; if a blow were struck on the dome of Notre Dame, the shock would be lost in the ground and would be transmitted there by the retaining walls or by the pillars, and by the flying buttresses. If a blow were struck on the malar bone, the two processes, frontal and maxillary, of that bone would transmit the vibrations through the superior maxillary and the frontal, whilst the zygomatic arch, a veritable cathedral flying buttress, would transmit them to the temporal. The base of the orbit resists the shock both like a Roman church and like a Gothic cathedral.

*Resistance of the Walls.*—The wall of the orbital cavity is extremely resistant from without; it is still solid below, but is thinner above, and paper-like within. Besides the thickness of its skeletal structures, the wall possesses in the mass of muscle covering the temple a most valuable defence, and on this side, which is really the only one exposed to traumatism, the eye is well protected. Moreover, when a blow reaches the external wall with sufficient force to cause fracture the track of the fracture cannot go very far; it is immediately checked above and below by the horse-shoe, concavity outwards, formed by the united sphenoidal and sphenomaxillary fissures.

The inferior wall is protected by the entire bulk of the face; to reach it, a projectile or a line of fracture must have in the first place involved the inferior maxilla and have crossed the antrum, besides, the wall is relatively thick, since it contains in its structure protection for an important nerve trunk, the intra-orbital.

The internal wall is slight, like the os planum of the

ethmoid which forms the greater part of it, but it is protected by all the ethmoidal cells, and is only reached when the traumatism has already produced great destruction in the surface of the opposite side. In this situation Nature has no need to oppose a strong barrier, the eye being protected by the actual thickness of the tissues and organs which separate it from the opposite side; the delicacy of the wall is not a disadvantage, so far as injury is concerned. But it is emphatically so from the point of view of the facility with which neoplasms, arising in the nasal cavities, affect the orbit, deflecting at first, and later perforating, the slight partition which separates them from the orbital cavity.

The superior wall of the orbit is equally thin, and more than this, it is at the same time orbital wall and cranial wall. It is this latter detail which explains why it is often injured. Of all the orbital walls it is perhaps that most often wounded, and this occurs because it can share in the cranial fractures (whose rôle will be studied later), and also because direct shocks on the superior orbital arch are easily conducted to it.

*Application of the Laws of Dynamics to the Orbit.*— In making use of the classic data put to profit by engineers and architects we can ascertain precisely and scientifically the manner in which the bones of the orbit offer resistance.

In the first place we may consider the structure of the bones which constitute the cavity; in the second place the specialised architecture of the orbital vaults.

(1) The bones of the orbit, like those of the cranium, are composed of two laminæ separated by spaces filled with bone-marrow; this separation is very favourable to resistance.

Thus, when a steel bullet is fired at a plate seven millimetres thick, it will pierce the plate of metal. Let this plate be split in two, and in the interval between the two plates, place sawdust, compressed

paper, or cork-powder; the bullet will not penetrate the two half-plates and their intermediate packing.

The projectile loses force in passing successively through media of varying density.

The frontal bone at its upper part, the malar bone, and the outer and inferior walls of the orbit may be compared to a metallic plate in two layers separated by a less dense substance, which is bone-marrow.

(2) Fig. 2 will demonstrate, without further words (save the accompanying explanation), how forces which attack the eye on the superior orbital region, on the malar bone, or on the inferior orbital region, act and are resolved.

### Vulnerability of the Orbit

The cavity of the orbit in general is well protected where it is closed, but Nature has decreed that it should be vulnerable by reason of its numerous and wide apertures.

We will not discuss the principal opening. The eye is very fortunate in avoiding injury attacking it from the front, although nothing protects it beyond the membranous shield of the eyelids. Yet this shield fails when the nature or the speed of the projectile render it invisible.

But it is not alone by the base of the orbit that the cavity is vulnerable. The cavity communicates by important orifices: (1) with the cranium by the optic foramen and the sphenoidal fissure; (2) with the soft tissue of the facial mass and the pterygo maxillary fossa.

The optic foramen, and especially the sphenoidal fissure, readily allow sanguinary effusions to pass from the base of the cranium. Orbital hæmatomata and exophthalmias occur, which are due solely to this cause, but it is especially the fissure and the pterygo-maxillary fossa which so well explain how injuries to this region may involve the eyeball. There is by this relatively large opening a ready communication between the orbital tissues and the soft parts, retro-

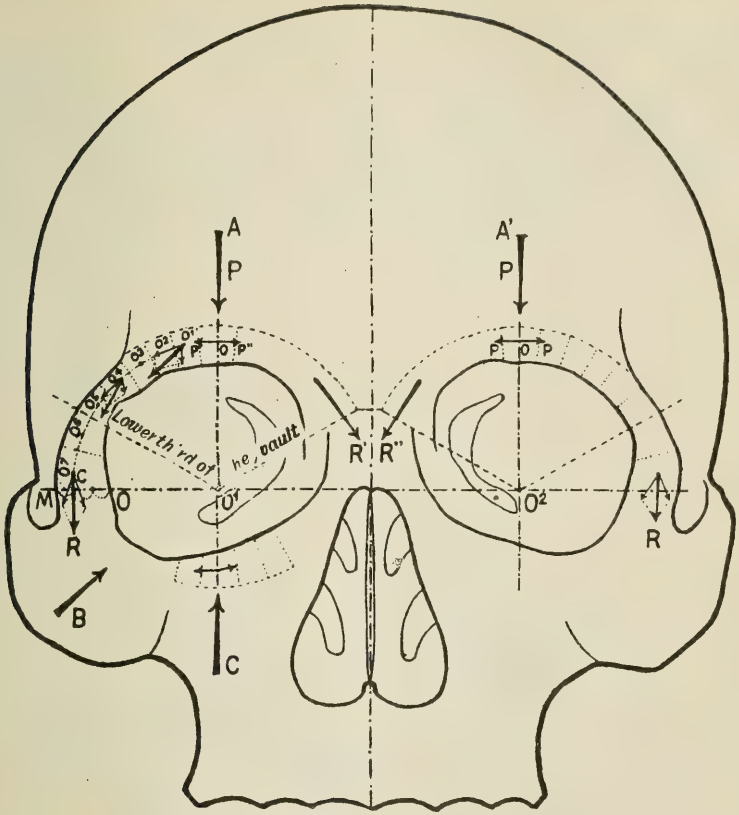



FIG. 2.—*Application of dynamic laws to the study of injuries to the orbit.*

A and A′. *Blow delivered on the superior part of the orbital arch.* This force divides into two components, thus: $P = OP' + OP''$. The total resultant of the forces due to propulsive force and weight must pass between O and C so that $MC = \frac{MO}{3}$; to obtain this result, it is necessary to enlarge the surface of the base of the courses (foundation): hence the presence of the malar bone.

The resultants R′ and R″ which converge towards the nose, being equal and opposite, neutralise each other (principle of bridge piers).

B. *Blow delivered on the malar bone.*—The force in this case is resolved into three other forces whose resultants are lost in the process of the frontal bone = zygomatic arch (flying buttress of Gothic cathedral) and maxilla.

C. *Blow on the maxilla.*—The shock is resolved into two forces. The resultant of one is lost in the malar bone and the second in the upper portion of the superior maxillary bone.

maxillary and jugular (Fig. 3). Let a bullet or a piece of shrapnel penetrate sharply, either into the facial bony mass, or the soft parts, or more frequently into both, then by virtue of Pascal's hydrostatic law the rapid vibrations which result are transmitted to the orbit by the pterygo-maxillary fissure; the eye is struck after the manner of a rock submerged in the

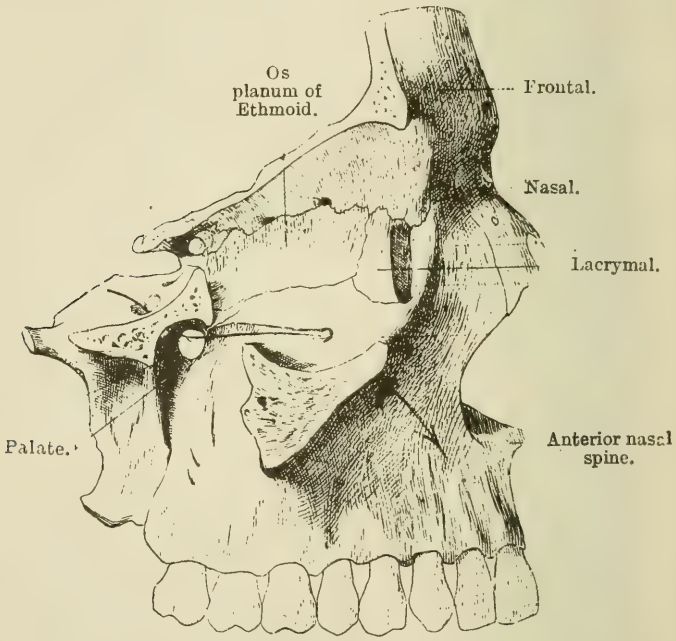



FIG. 3.—Pterygo-maxillary fossa (anterior wall and posterior opening).

sea and shaken by a deep wave. The first result of such a commotion in the orbit is the pushing forward of the eye as though to make it come forth from its normal situation, in spite of the optic nerve which resists and pulls it back, with more or less force, sometimes leading to rupture of the posterior part of the globe.

If we take into consideration the speed and the force of modern projectiles we shall understand that

the contents of the eye and its deep membranes cannot readily support such indirect and mediate traumatism, and that from it will result lesions, the descriptions of which will constitute one of the original features of the essay we have undertaken.

## *CHAPTER III*

# GENERAL CONSIDERATIONS UPON THE ÆTIOLOGY OF FRACTURES OF THE ORBIT

### Their Frequency, Varieties and Pathogenesis

Fractures of the orbit by projectiles of war hold an important position in actual warfare, and they are important especially from the effect they have upon the visual apparatus and upon the organs which occupy the vicinity of the orbital cavity.

The following is a synoptical table which will show to the reader both a general survey of the Service d'Ophtalmologie de la 18e Région and the importance of the subject we are engaged in studying.

### Fractures of the Orbit

609 *cases out of* 2554 *wounds inflicted in war.*

| | | Per cent. |
|---|---|---|
| (1) With preservation of the eyeball | 397 say | 65·5 |
| (2) With destruction of the eyeball | 212 ,, | 34·5 |
| (*a*) With preservation of the eye, without ocular lesion of any kind | 105 ,, | 17·2 |
| (*b*) With ocular lesions | 292 ,, | 47·9 |

These lesions are :—

| | | |
|---|---|---|
| (1) Detachment of the retina | 40 ,, | 6·5 |
| (2) Choroido-retinitis, atrophic and pigmented, macular and equatorial | 94 ,, | 15·5 |
| (3) Choroido-retinitis proliferans | 45 ,, | 7·3 |
| (4) Atrophy of optic nerve | 29 ,, | 4·7 |

| | | Per cent. |
|---|---|---|
| (5) Laceration of optic nerve | 4 say | 0·65 |
| (6) Section of optic nerve | 12 ,, | 1·96 |
| (7) Optic neuritis, or retrobulbar neuritis | 22 ,, | 3·6 |
| (8) Hæmorrhage into the vitreous | 31 ,, | 5 |
| (9) Total cataract | 7 ,, | 1·15 |
| (10) Subluxation of the lens | 2 ,, | 0·32 |
| (11) Corneal lesions alone | 6 ,, | 0·98 |

Furthermore, amongst these fractures we have observed :—

| | | Per cent. |
|---|---|---|
| (1) Complications in adjoining cavities— | | |
| Sinus { frontal | 31 say | 5 |
| Sinus { maxillary | 110 ,, | 18·2 |
| Brain | 13 ,, | 2·1 |
| (2) Complications of sensory nerves | 43 ,, | 7 |
| (3) Complications of muscles— | | |
| Extrinsic | 23 ,, | 3·77 |
| Intrinsic | 4 ,, | 0·65 |
| (4) Blepharospasm from lesion of the infra-orbital nerve | 2 ,, | 0·32 |
| (5) Cellulitis of the orbit | 2 ,, | 0·32 |
| (6) Complications of the lacrymal passages | 25 ,, | 4·1 |

The muscular lesions are divided thus :—

| | |
|---|---|
| (1) Paralysis of the levator palpebræ | 7 |
| (2) ,, ,, ,, superior rectus | 4 |
| (3) ,, ,, ,, inferior rectus | 4 |
| (4) ,, ,, ,, internal rectus | 2 |
| (5) ,, ,, ,, external rectus | 2 |
| (6) ,, ,, ,, superior oblique | 2 |
| (7) ,, ,, ,, inferior oblique | 1 |
| (8) ,, ,, several nerves simultaneously | 4 |
| (9) ,, ,, intrinsic muscles alone | 2 |

The fractures which bring about these affections may be divided into direct and indirect fractures; but they occupy in this respect positions singularly unequal; for while direct fractures are extremely

common in our service, it is impossible to quote more than two clear cases of indirect fracture. We must emphasise this clinical datum, which merits consideration.

*Indirect fractures* are sometimes fractures radiated from the superior portion or the base of the cranium to the orbital vault, or sometimes fractures by contre-coup ("independent," TRÉLAT), which continue the general directions of a line of cranial fracture. To judge from the classic authorities, and from the best of them, this type of orbital traumatism should form a prominent feature in the practice of ocular surgery, and cranial fractures—of which we do not need here to recall the numerous theories—should frequently implicate the sphenoid and the frontal in their orbital portion. Such is, however, not the case, for these lesions are extremely rare.

Doubtless the objection might be raised that such injuries have not come under our notice, because the cases have not had time to arrive at the base, where we have been engaged in the study of military ophthalmology, or perhaps still more that, amongst the important accidents experienced by the wounded, orbital injuries have passed unnoticed, and that general surgeons alone have been able to observe the variations in fractures of the vault of the orbit.

This latter objection loses all its force precisely because, in the Service Central de la 18e Région, we met with a large number of very important cranial injuries which we observed with particular care. These were cases of fractures of the skull in the parietal and occipital regions which presented visual trouble, and in particular, hemianopia. Our pupil, DR. BEAUVIEUX, has written an elaborate memoir on this subject, not yet published, dealing with cases in which cranial traumatism, always very important, was sometimes pre-eminent. It treats of fractures by bullet or by shell which have made great breaches in the cranial walls and often caused fractures to radiate to great distances.

In none of these cases has the optic nerve been implicated; in none of them have the structures passing through the sphenoidal fissure been damaged. We must conclude that there have not been fracture-radiations over the vault of the orbit; and if, indeed, such traumatisms have neither produced fracture by radiation nor independent fracture by contre-coup we must deduce that, in sound military ophthalmology, there is no need to attach importance to a lesion whose frequency has been singularly exaggerated in previous literature

Furthermore, we are not the only authors who have studied visual disturbances consequent on traumatism of the cranial regions which cover the visual psychic lobes; PIERRE MARIE and CHATELIN have published a very important essay on this subject in the *Revue de Neurologie* (December, 1915, Nos. 23 and 24). In this they report thirty-six observations of cranial fracture, of which thirty-one were complicated by hemianopic modifications of the fields of vision. In all these cases, save one, the authors have noted no damage to the transparent media nor to the deep ocular membranes, nor to the intrinsic or extrinsic muscles which might suggest a fissure radiating into the orbit. The diplopia mentioned in two or three of the cases has rapidly disappeared, and did not seem to be the consequence of attrition of nerve filaments at the site of the sphenoidal fissure.

In Case XXXI, however, MARIE and CHATELIN found a double optic atrophy, but they attribute it to a diffuse lesion of the chiasma, the patient having had a cerebral abscess with meningeal trouble.

We have had another proof of the extreme rarity of radiating fractures and fractures by contre-coup of the orbital vault; it is that we have never been able, in the numerous radiograms which we have had placed at our disposal, to see a fissure track indicating a solution of continuity of the vault extend as far as the sphenoidal fissure. We are quite aware that it is a difficult region to radiograph, and that this may be

the explanation of the absence of any trace of fracture upon our negatives; but as, on the other hand, there is no symptom indicating that the motor or sensory nerves of the eye have been damaged in the optic foramen or the sphenoidal fissure, it must be concluded that the orbital cavity in general does not suffer by radiation or contre-coup in the gravest gunshot fractures of the cranial vault.

Twice only have we found this condition; in one case the fracture was by radiation; in the other, by contre-coup. What are 2 out of 609 cases of fracture of the orbit?

The 607 other cases which have been examined by us have been direct fractures.

These *direct fractures* have been produced by bullets (150 times), by shrapnel (14 times) and by shell fragments (440 times). MENACHO has noted that more than half the orbito-ocular injuries were produced by bullets, because he studied the injuries at the outset of the campaign; later on, during the trench warfare, shells have played a much greater part. These injuries sometimes affected the wall of the orbit, sometimes the margins; it was the bullets especially that injured the walls, and they often perforated and traversed both orbits. All ophthalmologists have seen soldiers, both of whose optic nerves have been injured, sometimes divided by the same projectile. The pointed bullet, conical and endowed with great velocity, after having traversed the bony walls, readily passes into the neighbouring cavities. Shrapnel balls, on the contrary, having less velocity, very often remain in the orbit. We have removed a number of them with or without preservation of the eye; the same applies to shell fragments. Very rarely do they pass beyond the orbital cavity to lodge in the nose, the antrum, or the cranium; often, indeed, they are checked by the orbital wall, driving it in without passing through it, but they produce grave commotion in the contents of the cavity before coming to rest against one of the walls.

## Pathogenesis

Three theories have been advanced to explain the mechanism of *indirect fractures* of the orbit by gunshot wounds—

(1) The scattering of the projectile, fragments of which strike the internal wall of the cranium.

(2) The cone of air produced by the flight of the bullet is the true projectile capable of smashing the wall of the cranium.

(3) The hydrostatic pressure, based upon Pascal's law. The projectile when entering the cranial cavity produces a sudden increase of pressure which is transmitted with equal force over the whole internal surface of the cranium. The orbital vault being the thinnest portion of the cranial wall should therefore be frequently fractured.

The last theory would appear, *a priori*, to appeal to the judgment, and with Braquehaye and Chipault we were quite disposed to accept it, if clinical experience had demonstrated to us the existence of such fractures; but since, as we have said above, we have studied minutely all the visual signs of the very large number of cases which have suffered from the entry of projectiles into the cranium without meeting with a single instance in which the orbital roof was fissured, we cannot attach great importance to a theory which is not upheld by the facts. We do not further labour the point, but we wish to make use of the wealth of material at our disposal to point out that, in gunshot wounds of the cranium, fractures of the orbital roof are produced neither by radiation nor by contrecoup.

With the help of Dr. Beauvieux, who, moreover, has been our constant and painstaking assistant in all the researches with which this little book is concerned, we have examined 193 gunshot fractures of the cranium. There were well-marked bone injuries in the greater number of the cases; we have noted in the parietal and occipital regions a loss of substance

over a surface larger than a crown-piece; often the bullet had traversed the cranium from side to side, that is to say, the traumatism had fulfilled all the conditions necessary for the applications of PASCAL'S law, and yet never—*we repeat, never*—has the patient presented the least evidence of injury about the optic foramen or the sphenoidal fissure. Not a motor paralysis, not a sensory paralysis, not an atrophy of the optic nerve, has resulted from the mischief in the bony box of the cranium. As clinical observers, we are therefore perfectly entitled to affirm that gunshot fractures of the cranial vault are not accompanied by either fracture or radiation, or by fracture by contre-coup, such as to implicate the orbital roof and the optic foramen.

We do not deny the existence of fracture by radiation as they were described long ago by ARAN, and afterwards by all those who have studied the pathology of fractures of the skull (FÉLIZET, CHIPAULT and BRAQUEHAYE, etc.); further, we do not deny fractures by contre-coup ("independent," TRÉLAT), that is to say, those which, interrupted for a moment in their course, continue in the orbital vault the line of fracture of the cranial vault; but we do affirm that these fractures are the consequence of falls upon the head, of violence to the skull produced by blunt bodies, and that they do not follow gunshot injuries. From this point of view it will be well to quote the authorities here and to interpret them; we shall see that the clinical facts and experiments are not in disagreement with our point of view.

If we read attentively the excellent article by ROLLET upon fractures of the orbit in the *Encyclopédie d'Ophtalmologie* (Vol. VIII, p. 375 *et seq.*), we see, in fact, that the fractures radiated from the vault to the base are due to falls on the vertex. These radiations to the orbital vault are very common (23 out of 68 cases, PRESCOT-HEWETT; 79 out of 86 cases, DE HOLDER); but in these cases, when one is dealing with gun-shot fractures, it is a question of suicide, and under

these circumstances the orbit is necessarily implicated. Suicides fire a bullet into the mouth, or under the chin, or in a region adjoining the orbit, so that a fissure of the orbit is produced by direct shock. The same applies to the case quoted by ROLLET, of assassination by the blow of a spade on the orbital region. Here it was not a question of fracture of the cranium propagated to the orbit, but of a fracture of the orbit spreading to the cranium. In examining the 79 cases of fissure of the orbit cited by DE HOLDER, we find 53 cases of fracture of the optic foramen; of these 53 cases, 42 are fractures from gunshot; but in these 42 cases, 32 are shots fired into the mouth, and 10 into the temple and forehead. These are evidently not radiated fractures, but direct fractures of the orbital vault; in the 10 other cases it was a question of a fall, or of a crushing blow. It is very evident that DE HOLDER'S statistics in no way contradict our opinion, which is, that fractures of the cranial vault do not secondarily affect the orbital vault by radiation or by contre-coup; orbital fractures are direct, or do not occur at all.

Let us see what the authorities in military surgery say.

CHAUVEL and NIMIER write: "Besides these direct fractures, the orbital vaults are sometimes implicated by fissures radiating from a fracture of the cranial vault; we may even observe there true fractures at a distance and by contre-coup" (*Chirurgie d'armee*, p. 336). They are speaking, however, in a general manner; they nowhere say that gunshot fractures of the cranium radiate over the roof of the orbit; on the contrary (p. 294 *et seq.*) they write that "in crania fractured by projectiles the fissures are parallel to the direction of the violence, that is to say, antero-posterior in fronto-occipital shots, transverse when the projectile has passed from one temple to the other; when the wound is frontal, the two superior fissures on each side run horizontally from front to back and tend to rejoin at the occiput, thus circumscribing the

skull-cap by a circular fissure; the two oblique branches below and behind join the temporal fossa towards the base of the petrous portion; these fissures tend to detach the cranium from the bony mass of the face. In transverse gunshots, we again find the circular fissure, which instead of detaching the superior part of the bony vault from the inferior, seems to prefer to divide the cranium into two portions, anterior and posterior."

CHAUVEL and NIMIER nowhere mention fissures radiating from the cranial vault to the orbit.

DELORME writes: "In bi-temporal, bi-parietal, and bi-occipital perforations, we sometimes see fissured radiations towards the base, but they are relatively rare. The fissures have a tendency to take the circular direction rather than the vertical" (*Traité de Chirurgie de guerre*, Vol. II, p. 547); and further, on p. 553, DELORME says again, concerning indirect fractures or those by contre-coup, that "of a large number of crania which we have opened after having fractured or perforated them by projectiles, we have not been able to discover one."

The assertion which we have made on the other side, and which at first might have caused surprise, is therefore quite in accord with classic findings, whether they belong to the clinical or experimental order; and we might write here this aphorism: "Gunshot fractures of the cranial vault lead neither to fractures radiating into the orbital roof nor to fractures by contre-coup."

Fractures of the orbital vault and of the optic canal, when they are produced by radiation, are the result of falls on or violent contusions of the vertex; more often they result from direct blows in the region of the orbit; gunshot of the forehead, contusion of the superciliary arch, fractures by telescoping, due to a fall upon the feet.

The ætiology and pathology of *direct fractures* need not detain us long; one expects to find that gunshot wounds often affect the circumference of the orbit and

its walls; we note the possibility, and even the relative frequency and gravity, of isolated fractures of the superior wall with integrity of the margin. The margin, thanks to the arrangement we have pointed out above (Fig. 2), has resisted, but the orbital vault, extremely thin, has yielded to the influence of the oscillatory vibrations imparted to neighbouring tissues by the violence of the blow. Grave accidents are to be anticipated to the optic foramen (atrophy of the nerve), and on the side of the brain (meningo-encephalitis), as a consequence of these latent fractures.

The projectile which smashes the superior border of the orbit often implicates the frontal sinus. LEGOUEST has reported the case of an officer who carried a bullet for eighteen years in this sinus, when it fell spontaneously into the pharynx.

The internal wall of the orbit is more fragile; it is easily perforated, even by small missiles. We have seen fragments of grenade perforate the os planum and lodge in the ethmoid, where, moreover, they are often well tolerated.

One of the most frequent amongst the injuries of war is that which affects the malar bone. It may be carried away by a bullet or crushed by a shell fragment. In a case of DELORME'S, a bullet struck obliquely the infero-external angle of the orbit and loosened a corner of the bone. Very often the bullet or shell fragment does away with the malar bone, destroys the eye, and in passing out leaves a notch in the supra-orbital arch.

Fracture of the external wall of the orbit is, *par excellence*, that which results from attempts at suicide; it has, however, not been rare in our experience, and reports will be found later. Sometimes a bullet perforates the two orbits and severs or destroys both optic nerves without touching the eyes. In several of our cases the bullet has entered near the tragus, traversed the orbit from behind forwards, from without inwards, and from below upwards, severing the optic nerve and emerging at the root of the nose.

Fig. 35 gives the ophthalmoscopic appearance in an old avulsion of the optic nerve, as well as Fig. 1, Plate III.

If we wished to enlarge upon the ætiology of these fractures of the orbit, we should only have to take one by one the cases cited later and expatiate on their peculiarities. Perusal of the case reports and the examination of the tables which accompany them will suffice.

Moreover, the pathology of the conditions resulting from direct fracture of the circumference and walls of the orbit is only interesting so far as it concerns the injuries to the orbital contents (including the eye). Lesions of the skeleton evidently depend upon the propulsive force of the wounding agent, its mass and its form; they depend also upon the point struck; when the projectile meets the malar bone, as very frequently happens, it causes a comminuted fracture of that bone and often lodges in its substance. There are no radiated fractures, because the pterygo-maxillary fissure checks the course of the fracture; on the other hand, when the wounding agent strikes the frontal bone at the level of the superior orbital margin, the violent contusion of this bone is accompanied by a fracture of the orbital vault spreading to the sphenoidal fissure and the optic foramen, implicating the very important organs found in this neighbourhood.

If the reader will add to these considerations what has been said above on the subject of the resistance of the orbit to traumatism, he will be in possession of all that concerns the pathogenesis of fractures; what remains to be said will be more appropriate when we come to speak of the various visual troubles which these fractures provoke.

## *CHAPTER IV*

# FRACTURES OF THE ORBIT WITH PRESERVATION OF THE EYEBALL

We shall divide the fractures of the orbit, from the point of view of their effects on the visual apparatus, into two great classes—

I.—Those in which the globe is preserved.
II.—Those in which the globe is destroyed.

We shall commence by speaking of the first, and we shall place immediately before the reader the chief data, viz. the principal clinical demonstrations gained from our experience.

### § I.—The Laws Governing the Affections of the Visual Apparatus in Injuries of the Orbit with Preservation of the Eyeball

(1) When the projectile passes above the orbit, implicating the frontal bone and the anterior cerebral region, it produces fractures of the orbital vault affecting the sensory, motor, and optic nerves in the region of the optic foramen and the sphenoidal fissure. The eyeball is not involved.

(2) When the projectile passes below the eyeball without traversing the orbit and without fracturing it, it produces concussion affecting the eye in the macular region. This is the great cause of diminution or loss of acuity of central vision.

(3) When the projectile has fractured the orbit, crushing in the wall more or less, without touching the eyeball, it produces in the globe grave concussion

injuries, macular lesions and choroidal ruptures. Macular lesions occur, irrespective of the wall damaged, whether external, internal, or inferior.

(4) When the projectile has traversed the orbit without touching the eyeball, it produces the same disorders together with those which result from the laceration of the organs contained in the orbital cavity. The optic nerve is often divided; the papilla is then lacerated as if torn away.

(5) When the projectile grazes the eyeball tangentially, without rupturing it, or when the globe is touched by the orbital wall being driven in upon it, it causes damage in immediate relationship with the bruised point (choroido-retinal lacerations with detachment of the retina and retinitis proliferans); the macular region is often involved in the damage, but it is not injured alone.

If these laws were based only on theoretical considerations they would certainly be ill-founded, but they rest on the study of cases, upon clinical evidence, and it is for this reason that we desire to make them known.

The case-reports are divided into two categories :—

*First Category.*—Fractures of the orbit with preservation of the eye, without retention of a foreign body.

*Second Category.*—Fractures of the orbit with preservation of the eye, with retention of a foreign body.

## First Category

The first category of case-reports is divided into five groups.

### First Group

**Fracture of right orbit by rifle bullet.** (Case 1.)

C. T., Cavalry, wounded May 10, 1915, at L. A rifle-bullet had penetrated the left supra-orbital region, at 1 cm. from the end of the eyebrow, and emerged from the right supra-orbital region near the temporal fossa, 2 cms. in front

of the temporo-maxillary articulation (Fig. 4). T. lost consciousness for twenty four hours and was trephined the next day.

Condition on admission, Jan. 15, 1916. The aperture of entrance of the projectile is extremely painful to the touch. The zone of emergence is very excavated, like a cupola; at this point there is depression of the bones, frontal and temporal, near the suture between the two bones, a little behind the external orbital process. No cerebral pulsation.

There is a fracture of the right superior orbital margin,

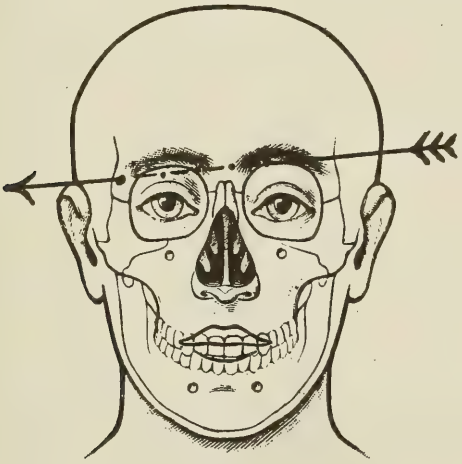


FIG. 4.

the seat of a large notch, and there is visible here a sinus from which purulent liquid wells up.

The right upper lid has ectropion; closure of the eyelids is almost impossible because of this vicious cicatrix. No defect of movement to the right or left.

Hyperæsthesia of nasal, frontal and lacrymal nerves is to be noted on the right side; they have all probably been implicated in the traumatism propagated to the sphenoidal fissure.

No lesion of the eyeball; median and deep membranes are intact.

R. and L. V = 9/10.

The central and peripheral nervous system is normal; no meningeal reaction.

**Fracture of the superior wall of the left orbit and frontal sinus by shell fragment.** (Case 2.)

R. M., Infantry, wounded May 4, 1916, at V.; shell wound left superior orbital region. Trephined May 6, at Saint-Dizier, with extraction of bone splinters. Slow recovery owing to suppuration. (Fig. 5.)

Condition on admission, June 15, 1916. There is an incision about 3 cm. long at the level of the superior margin of the left orbit, parallel with the superciliary arch. Another cicatrix is to be seen at right angles to this arch meeting the first incision at its external third.

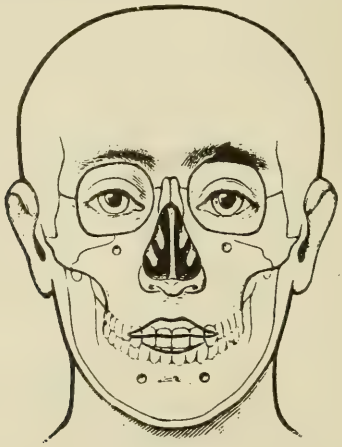


Fig. 5.

This cicatrix, not painful, is the seat of a slight depression following fracture of the subjacent layer of bone; no cerebral pulsation perceived.

Radiogram confirms fracture of the superior orbital margin.

There is insensibility of the left frontal region following section of filaments of the frontal nerve.

The left eye is absolutely intact; no lesion of the media or of the choroid or retina.

L. E. with + 1 D cyl. axis 90°, V = 5/10.

R. E. V = 1.

Diminished acuity of vision in left eye, explicable by injury to optic nerve in its bony canal.

**Fracture of the right superior orbital margin with consecutive atrophy of the optic nerve.** (Case 3.)

A. G., Infantry, wounded May 10, 1916, by grenade explosion, in the right supra-orbital region. Fragment extracted at B. On admission, Sep. 3, 1916, there was a cicatrix 1 cm. long in the middle of the right eyebrow. Palpation of the superior orbital margin reveals a notch in the bone, admitting the tip of the index finger; no foreign body to be felt. The patient found almost immediately that he could not see with the right eye.

This eye has slight external strabismus following the amblyopia; it is normal outwardly. No extrinsic muscular paralysis; the dilated pupil is insensible to natural stimuli. The consensual reflex from right to left is abolished, but persists from left to right. No injury to transparent media. The optic disc is the seat of complete white atrophy.

R. E. $V = 0$.

The left eye had suffered from a foreign body in the cornea, which had been extracted at B.

L. E., with + 0·5 D cyl. axis 0 $V = 7/10$.

## Second Group

**Fracture of both orbits by bullets.** (Case 4.)

A. R., Infantry, wounded Jan. 11, 1916, by a bullet fired from a distance of about eighty metres.

Leaving the military hospital at Chalons, Jan. 14, he entered our hospital on Feb. 23.

*Condition.*—The bullet had penetrated near the inferior border of the left orbit, quite near the inner inferior angle, in the lacrymal region, and came out near the right zygomatic arch, 3 cm. in front of the tragus. It had therefore traversed the nasal fossæ. At the aperture of exit there is to be felt a cicatrix adherent to the subjacent bone.

Examination of the nose shows a transfixion wound with intra-nasal adhesions.

The tip of the index finger detects, by the inferior external angle, a crack in the floor of the left orbit, a crack which appears to be prolonged far backwards. On the internal wall of the right orbit is an exostosis which impedes deep palpation of the cavity.

*Ocular Examination.*—The right eye, visual acuity = O, is outwardly normal. At the posterior pole is a large choroido-retinal rupture (concussion lesion); the whole of the papillo-macular region is the seat of patches of choroido-retinitis, pigmented and proliferating, secondary to hæmorrhage into the deep membranes (Plate III, Fig. 3).

The lower eyelid, slightly œdematous, is in a state of cicatricial ectropion at the inner angle.

The left eye is normal.

L. E. V = 10/10.

No injury to the transparent media or the deep

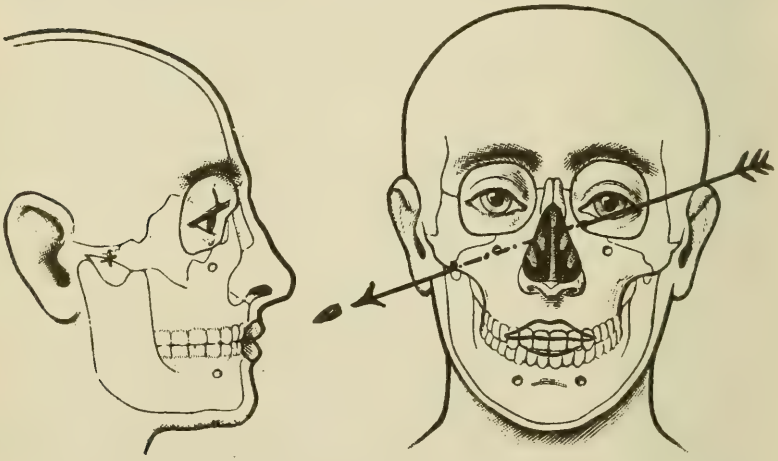


Fig. 6.

membranes. At the aperture of entrance suppuration from bone persists : some sequestra have been eliminated.

Condition stationary, June 20, 1916.

**Fracture of both orbits by rifle-bullet, hæmorrhage into the vitreous body R. E. ; macular choroiditis L. E.** (Case 5.)

L. M., Infantry, wounded Sep. 25, 1915, at S., by a rifle bullet, which traversed the facial bones from side to side. He did not lose consciousness. Admitted Sep. 27.

The bullet penetrated at the level of the zygomatic arch of the left side, about 5 cm. from the external auditory meatus and 3 cm. from the orbital margin. The orifice

of exit is a little below the right orbital margin, near the external angle of that orbit (Fig. 7).

Its course is therefore from left to right, and slightly from below upwards. In its course the projectile has fractured the floor of the left orbit, the nasal fossæ, the internal wall of the right orbit, and traversed the cavity in its lower part.

On admission no exophthalmos could be noticed.

The ocular lesions which L. presented are as follow—

R. E.—The vitreous body is the seat of a profuse hæmorrhage, preventing any red reflex. Little by little this

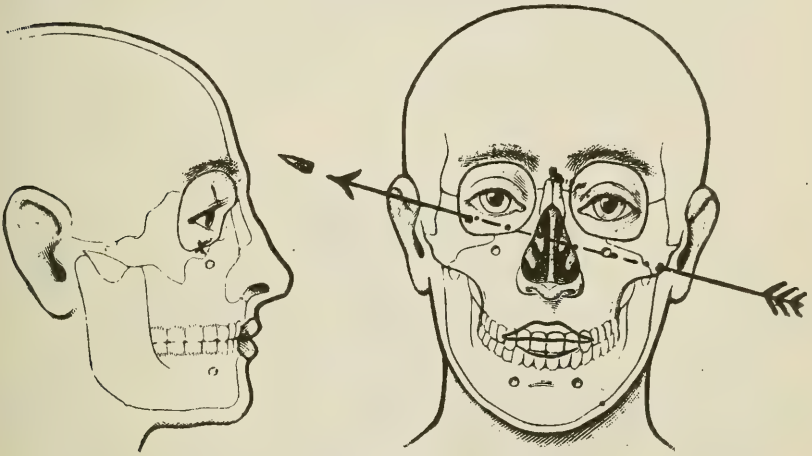


Fig. 7.

hæmorrhage became absorbed, and by April 4, 1916 there were—

(1) Large patches of whitish choroido-retinitis, star-shaped, in the macular region (concussion injuries).

(2) Large fibrous bands covering the optic disc, which is invisible to the ophthalmoscope (retinitis proliferans).

(3) Atrophy, with some pigmented foci disseminated about the inferior region of the retina and choroid, in the track of the bullet (contact lesions).

R. E. $V = 0$.

The eye has slight external squint.

L. E.—Sep. 27, the visual acuity of this eye was 3/10 barely.

Transparent media are intact. There is a cherry-red coloration extending over the whole macular field (concussion lesion), and a sprinkling of choroido-retinitis at the lower part.

April 4, 1916, on his discharge, the acuity of this eye had slightly diminished.

L. E. V = 2/10 barely.

**Bullet traversing the face, bilateral macular hæmorrhage.**
(Case 6.)

M. R., Infantry, wounded March 12, 1916. Admitted May 13, from Chaumont, viâ Orleans.

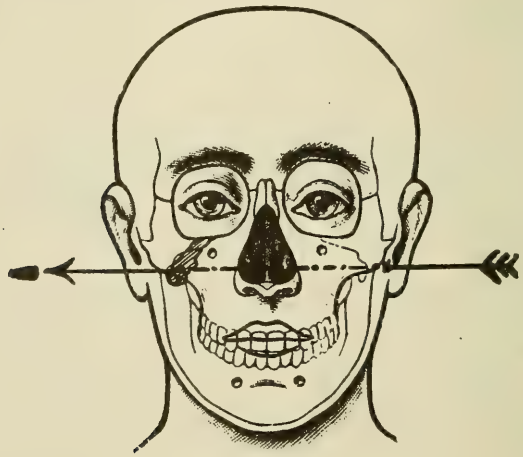


Fig. 8.

*Examination.*—A rifle bullet, from about 150 metres, had penetrated the left masseteric region, 3 cm. below the middle of the zygomatic arch and 2 cm. in front of the superior insertion of the lobule of the ear, in the interval comprised between the ascending ramus of the inferior maxilla and the coronoid process.

The orifice of exit, represented by a star-shaped cicatrix, adherent to the underlying fractured bone, is situated 4 cm. below the external angle of the right orbit and 7 cm. in front of the lobule of the right ear. The projectile has therefore traversed the face in a slightly oblique direction, from behind forwards and from left to right.

Palpation reveals on the right orbital margin, exactly in its middle, a loss of bone substance forming a notch of about 1 cm. (Fig. 8).

*Examination of the Eyes.*—R. E.—The eye is outwardly normal; no opacities in the media. The ophthalmoscope reveals a hæmorrhage of the macular region (concussion lesion), without other lesions of retina or choroid. Disc intact. The visual field shows the existence of an absolute central scotoma.

R. E. V = 1/50.

L. E.—Similar integrity of the transparent media and the deep membranes, except in the macular region, the seat of a slight hæmorrhage, cherry-red in colour (concussion lesion). The perimetric examination shows the presence of a relative scotoma.

L. E. V = 3/10.

## Third Group

**Fracture of the right orbit by a bullet, laceration of the choroid ; optic atrophy, R. E.** (Case 7.)

F. M., Infantry, wounded Oct. 31, 1914, near S. (Marne), by a rifle bullet. From Chalons he was sent to the Complementary Hospital No. 18 at Bordeaux, where he was admitted Dec. 4, 1914.

*Condition.*—The projectile entered the cheek on the left side, three fingers' breadth in front of the angle of the mandible, one finger's breadth above the lower border of the same bone. It divided the alveolar border of the maxilla, breaking the premolar and two molars ; it crossed the mouth, slightly wounded the dorsum of the tongue, perforated the palatine arch near the median line, traversed the right nasal fossa and the right antrum, smashing in the floor of the orbit, and came out in the temporal fossa, near the orbital margin, at the level of the angle made by the malar bone with the external angular process of the frontal bone (Fig. 9). The bullet passed beneath and behind the eye without touching it.

At the time of our examination the right eye was proptosed; it deviated downwards and outwards, but there was no diplopia because of the low visual acuity of the eye.

No lesions of the anterior segment or the appendages of the eye were remarked.

The vision of this eye is quantitative. In the macular region there is to be seen a vast laceration of the choroid, extending by an arciform prolongation beneath the disc and resulting from concussion transmitted to the posterior pole of the eye. The optic nerve is in a fair way to almost complete white atrophy.

The visual field is not measurable.

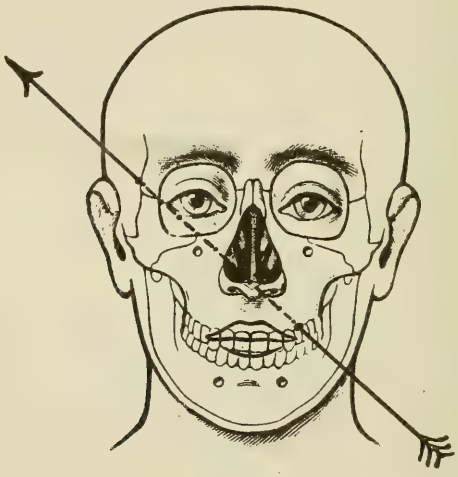


FIG. 9.

The left eye is normal. Acuity equals 7/10 and the visual field is lessened by 10° in all directions.

M. intermittently removes pus from the right nostril; there is a deviation of the septum to the right and a thickening to the left, resulting from the seton-like wound.

He was discharged Feb. 12, 1915, in the same condition.

**Wound of the facial bones by rifle bullet; macular and peripheral choroido-retinitis, R. E.** (Case 8.)

J. D., Sergeant, Infantry, wounded by rifle bullet, Nov. 3, 1915, at M.

The bullet, fired at close quarters, penetrated 1 cm. above the left zygomatic arch, and came out at the middle portion of the inferior orbital margin, where a depression exists in the bone in which one could place the tip of the index finger

(fracture of right orbital margin). At the level of the velum palati the orifices of entry and exit of the projectile are visible as it emerged from the facial mass. (Fig. 10.)

*Condition.*—The wound was cicatrised when we examined D., who complained that he could no longer see with the right eye.

This eye presented the following lesions, which are indirect, by contre-coup, by concussion, the projectile not having touched the eyeball.

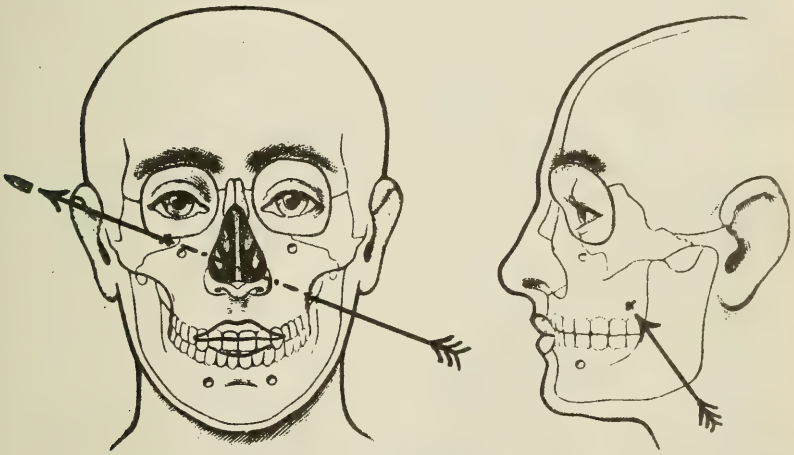


Fig. 10.

In the macular region there is a greyish white discoloration with pigmented spots, explaining the feebleness of visual acuity.

R. E. $V = 1/100$.

The visual field shows loss of central vision and defect in the superior peripheral field.

In the lower and outer part, *i. e.*, in relation with the aperture of exit of the projectile, the retina and choroid are greatly disturbed; laceration of the choroid with large patches of white atrophy and pigmented foci, probably secondary to a hæmorrhage *en nappe* of the deep membranes (contact lesions). (Plate I. Fig. 3.)

The left eye is intact, and its visual acuity normal.

At the end of three months the condition remained

stationary, and it is probable that these affections undergo little change.

**Fracture of the external wall of the right orbit ; macular choroido-retinitis ; avulsion of optic nerve.** (Case 9.)

J. L., Infantry, wounded at the Dardanelles, transported unconscious in hospital ship : he went to Egypt and thence to Marseilles.

*Condition.*—From the inferior external part of the right lower eyelid there commences a non-adherent arciform cicatrix, which passes 4 cm. behind the extremity of the eyebrow and is directed towards the upper portion of the temporal region. In the median portion of the wound is to be felt a little bony depression, which leads to an extensive fracture of the outer wall of the orbit, most marked above and behind, due to driving in of the orbital wall.

The right eye is outwardly normal. The pupil is slightly deformed because of a leucoma adhærens down and in. The vision of this eye = 0. There are floating opacities in the vitreous, but the lens has preserved its physiological transparency.

The deeper membranes are the seat of serious damage.

In the papillo-macular region, in place of the papilla there is a large atrophic zone, with, in the centre, a tinge of seagreen which seems to be due to a light fibrinous organised clot. The disc has disappeared under the mass of retinitis proliferans. There is also a narrow elongated laceration, somewhat arched, yellowish in colour, situated slightly below the macular region.

The globe has normal tension. Radiography has given a negative result as regards the possible presence of intra-orbital foreign bodies.

The left eye is normal.

Condition remained stationary until discharge from hospital, April 22, 1916.

Dec. 10, 1916, we again examined this case with the ophthalmoscope. The fundus of the eye, less encumbered by exudation, presented the condition shown in detail in Plate III, Fig. 1.

It is a perfect type of avulsion of the optic nerve (Plate III, Fig. 1).

**Fracture of the external wall of the left orbit by rifle bullet ; traumatic choroido-retinitis, L. E.** (Case 10.)

R. D., Sergeant, Infantry, wounded April 25, 1915, at E. A rifle bullet had wounded the left external orbital region. The projectile had struck the lower and outer part of the left orbit and had come out a little in front of the left temporo-maxillary articulation. In its course it had fractured the zygomatic process and the external wall of the left orbit.

On admission, a large furrow, very deep, is seen on the left cheek; the cicatricial tissue adheres firmly to the underlying tissues.

Paralysis of the filaments of the facial nerve going to the orbicularis inferior was noted, whence a slight ectropion of the lower eyelid and lagophthalmos.

No disturbance of sensation.

Radiography yielded a negative result, both as to the possible presence of splinters and the nature of the fracture.

The eyeballs are normal exteriorly. Visual acuity R. E. = 10/10.

In the left eye the transparent media are intact, but there are grave injuries to the retina and choroid.

(1) In the region of the macula, an extensive cherry-red patch, resembling a hæmorrhage and giving rise to a central scotoma.

(2) In the superior and inferior peri-macular region, patches of atrophic and pigmented choroido-retinitis, secondary to choroidal hæmorrhages.

These damaged tissues explain the feebleness of visual acuity, which is 1/50; they are due to concussion of the region; the eye has not been touched.

Feb. 4, 1916, restoration of the vicious facial cicatrix was attempted by means of an adipose graft. Results excellent, and the case was discharged as a convalescent, April 3.

## Fourth Group

**Fracture of the orbit by a shrapnell ball ; section of optic nerve, neuro-paralytic keratitis.** (Case 11.)

H. B., Lieut., Zouaves; wounded Sep. 23, 1914, at Tr. The first-aid dressing was applied immediately after the injury, and reapplied at the dressing station. This officer

was afterwards sent to Compiègne, thence to Angers and Bordeaux, where he arrived Sep. 27.

*Condition.*—He was struck by a shrapnel ball at the moment of looking out of the trench. Sensation of having the eyeball torn out, with free temporal hæmorrhage and slight epistaxis. Le médecin-major de l'ambulance diagnosed hæmatoma of the orbit, which leads one to suppose that considerable exophthalmos existed from the outset.

The wound is very small, like a bullet-wound; it is situated at the superior external angle of the left orbital

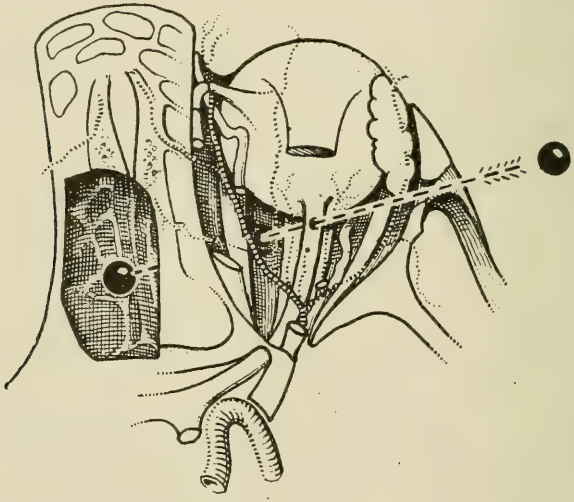


Fig. 11.

opening. There is marked exophthalmos, so that the cornea cannot be protected, closure of the lids being impossible.

The cornea is quite insensitive, save in its internal quadrant.

The pupil is dilated and immobile.

Examination of the fundus of the eye shows the typical picture of avulsion of the optic nerve; papilla invisible, covered by abundant hæmorrhage which extends far into the neighbouring retina and choroid; the posterior pole presents, moreover, milky white coloration due to traumatic retinal œdema, especially in the macular region.

Radiographic examination shows a shrapnel-ball, which after having crossed the left orbit, has perforated the os

planum, traversed the nasal fossæ, and come to rest in the right ethmoid, very near the partition and the right orbital cavity (Figs. 11 and 12).

In the days following the appearance of a neuro-paralytic keratitis was noted. Under the influence of astringent dressings the corneal ulceration improved, and there was diminution of conjunctival chemosis and exophthalmos.

On Oct. 29, 1914, extraction of the projectile was attempted. Incision outlining the wing of the left nostril, passing along the nose in front of the lacrymal region; section of the nasal bone by bone-forceps. The septum was

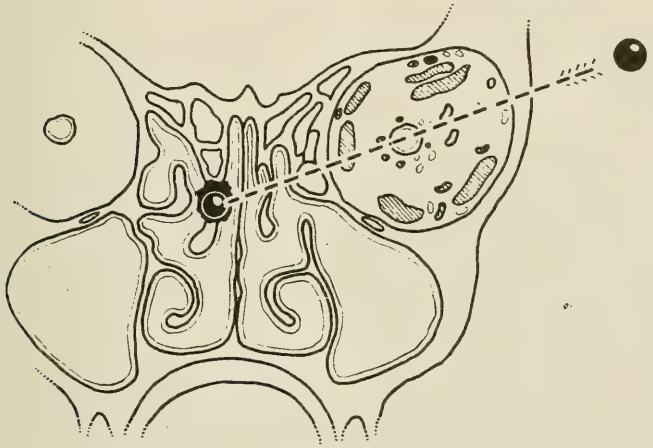


Fig. 12.

found to be much distorted. With a curette the track of the projectile could readily be traced, and it was easily extracted. Sutures. After-history normal.

Jan. 20, 1915. Notes on discharge—

L. E.—Loss of vision, consequent on section of the optic nerve. Mydriasis. Very slight corneal nebula. Perfect preservation of the globe and of its movements.

R. E.—Normal.

**Fracture of the left orbit by bullet, section of left optic nerve; laceration of choroid, L. E. Detachment of retina, R. E.**
(Case 12.)

Y. G., Algerian Sergeant; wounded Aug. 23, 1914, at O., by rifle bullet; was made prisoner on 25th. Went to

Charleroi and Düsseldorf. Returned as seriously wounded. G. came under our care Dec. 3, 1914, with a certificate attesting the seriousness of his condition.

*Examination.*—Injury by rifle bullet from distance of about 200 metres. The bullet entered the right cheek-bone and emerged from the left temporal fossa, two fingers' breadth behind the orbital arch. The projectile has not traversed the right orbit; it has broken the floor at the level of the malar bone and also near the internal angle (two fractures), traversed the nasal fossæ, and finally left the orbit (Fig. 13).

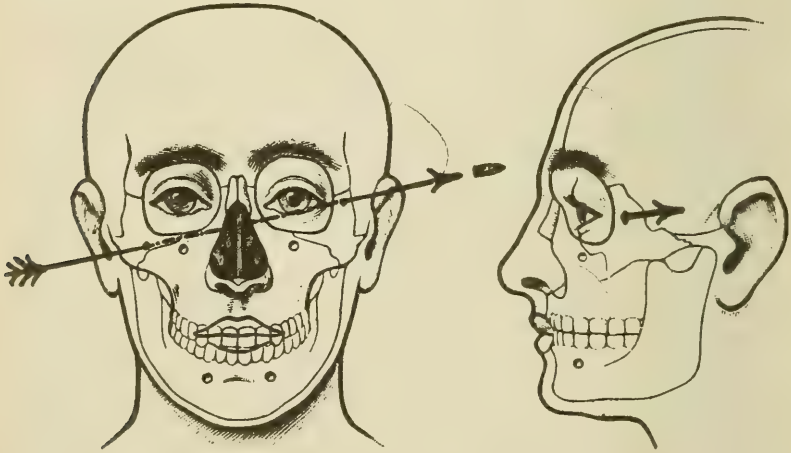


Fig. 13.

In its course it has caused the following injuries :—

R. E.—In the vitreous there are numerous floating bodies. Below and to the outer side are seen an extensive retinal detachment and concussion lesions extending to the macula. The upper part of the visual field is lost to near the point of fixation.

R. E., with + 1 D sph., V = 3/10 barely.

L. E.—The left optic nerve has been divided by the bullet; it is in a state of complete white atrophy; the vessels are normal. There is also a rupture of the choroid in the macular region with pigmentary deposit between the macula and the disc.

L. E. V = 0.

These injuries are produced by contusion and immediate pulling on the left eyeball at the moment of injury.

The retinal detachment of the right side was treated for two months (rest, compression, NaCl, etc.); on his discharge it was still present, and visual acuity remained about 3/10.

**Fracture of both orbits ; retinal hæmorrhage, R. E. ; retinitis proliferans, L. E.** (Case 13.)

A. G., Corporal, Infantry, was wounded at N. O. May 29, 1915, by a rifle bullet which traversed the face. Admitted, July 9, 1915.

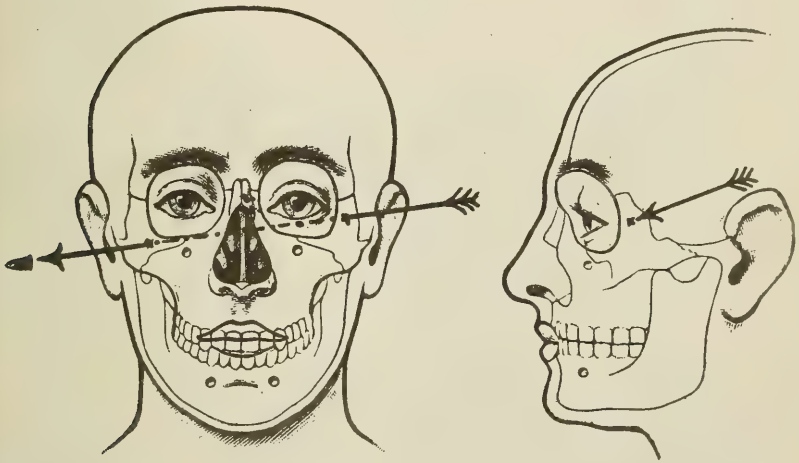


Fig. 14.

*Condition.*—The bullet entered by the left temporal region and emerged from the right temporal region. The course, slightly oblique from left to right and from above downwards, passes behind the external orbital margin, under the left optic nerve at the level of the posterior pole, and nearer the equator when passing the right eye. The projectile has, therefore, caused a fracture of both orbits (Fig. 14).

In the right eye numerous retinal hæmorrhages in the lower part are to be seen, corresponding to a partial loss of the upper part of the visual field. Macular and para-macular lesions from concussions; right eye not touched.

On the left side, numerous tracts of proliferating retinitis. In addition there are little hæmorrhagic patches to the outer side and below. In the vitreous are numerous flocculi; left eye probably touched.

The visual field is the seat of an extensive central scotoma.

R. E. V = 1/10.
L. E. V = 1/200.

G. has great difficulty in opening his mouth, due to a lesion of the temporal muscles. There is anæsthesia of

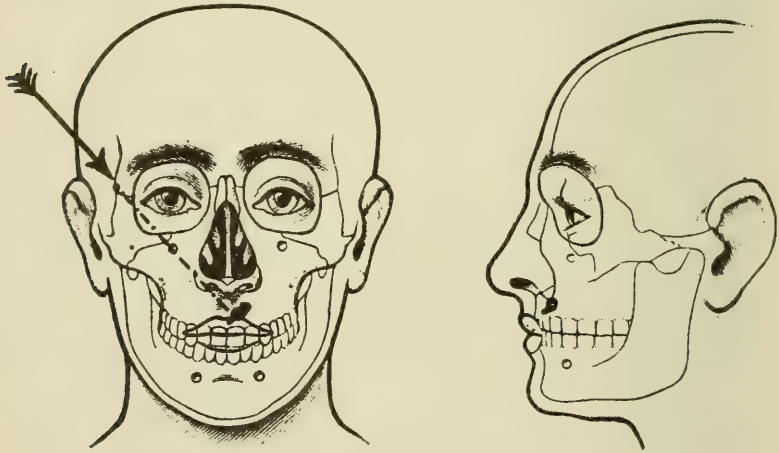


Fig. 15.

both infra-orbital nerves extending to the lower eyelid, the ala of the nose and the upper lip, more marked on the left side. He left hospital July 22, 1915; state of both eyes as on July 10.

**Fracture of right orbit, shell wound; rupture of choroid, R. E.**
(Case 14.)

A. St. P., Infantry, wounded Aug. 22, 1914, at L.; from Lunéville, he was admitted Dec. 7, 1914.

*Condition.*—The fragment has penetrated the temporal region a finger's breadth from the outer extremity of the eyebrow. It has crossed the orbit from above downwards and from behind forwards to lodge in the roof of the palate, where radiography revealed it, and where it still

remains (Figs. 15 and 16). The wound has been cicatrised for a long time. St. P. states that he noticed the loss of vision in the right eye immediately after the injury.

The right eye is slightly deviated downwards and outwards, due to paresis of the inferior oblique.

The anterior segment is normal; the pupil, which is equal to that of the other eye, reacts feebly to natural stimuli.

R. E. V = 1/200, not improved by glasses.

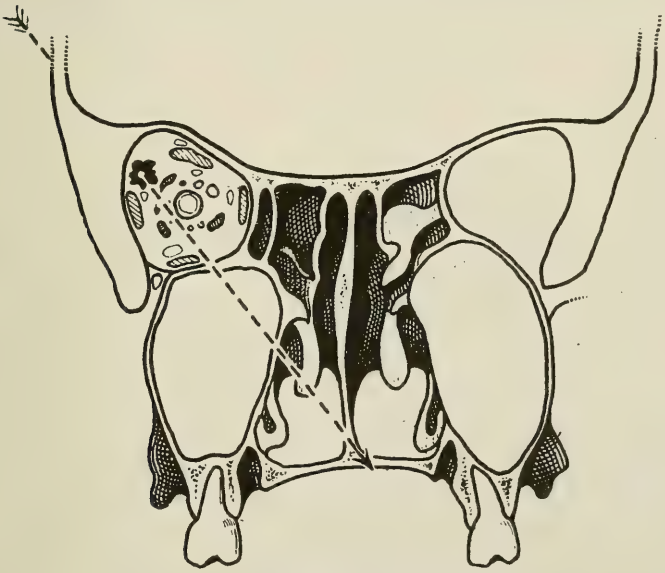


FIG. 16.

With the ophthalmoscope detachment of the retina is seen below; near the posterior pole, in the region of the macula, are extensive lesions of the retina and choroid (probably lacerations), pearly white with some spots of pigment along the borders. Lesions due to concussion; eye not touched.

There is, in addition, paræsthesia in the region supplied by the right frontal nerve.

Left eye normal, acuity = 9/10.

St. P. underwent no surgical interference, and on his discharge, Feb. 6, 1914, his condition remained stationary.

## Fifth Group

**Fracture by bullet of the floors of both orbits; double retinal detachment; macular lesion on the left by concussion.** (Case 15.)

C., Adjutant-chef, Infantry, wounded Sep. 14, 1914, at C. From the divisional ambulance to Fismes and thence to Bordeaux, where he arrived Sep. 19.

*Condition.*—A rifle bullet, entering the right malar region near the lower and outer angle of the orbit emerged at a point almost identical, near the infero-external angle of the left orbit.

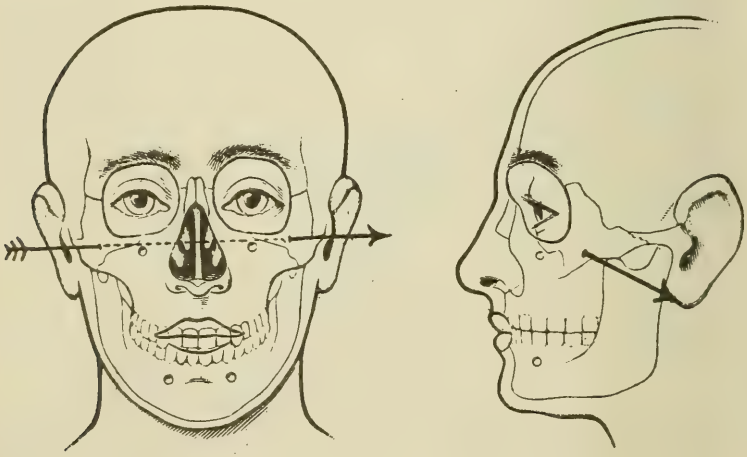


Fig. 17.

The aperture of exit is very extensive, about the size of a crown-piece.

The ocular affections were noticed immediately after the injury.

The right eye is outwardly normal; there exists no trace of wound or contusion of the appendages or of the anterior segment. Pupil dilated; tension manifestly diminished (T. — 1). R. E. V = Quantitative. The visual field persists in the temporal segment.

Ophthalmoscopic examination discloses a detachment of the retina, leaving only a small portion of the nasal area *in situ;* the right eye has been injured by the movement of a fragment of orbital bone (contact lesions).

The tension of the left eye is equally subnormal (T. — 1). Acuity barely 1/20. The visual field shows a lacuna in the temporal region, corresponding to a retinal detachment limited to the nasal portion. The vitreous is the seat of numerous floating bodies, due to hæmorrhage.

There is also to be noted anæsthesia of the regions supplied by the infra-orbital nerves (upper lip, supplied by anterior dental). C. also complains of a running of tears from both eyes, indicating that the nasal canals of the lacrymal passages have been damaged by the projectile.

Usual treatment for retinal detachment.

Feb. 16, 1915, condition as follows :—

R. E. V = Quantitative.
L. E. V = 1/10 good.

No modification of the visual fields. The retinal detachment on the right is extensive, principally below and to the outer side, and in the macular region.

On the left side the disc is pale and surrounded by pigment. The detachment is lessening, but in its place are large patches of choroido-retinitis in the macular region: right eye not touched (concussion lesions).

C. was discharged Feb. 20, 1915.

**Fracture of left orbit by bullet; detachment of retina, L. E.**
(Case 16.)

E. V., Infantry, aged 31, was wounded at Cr., Oct. 12, 1914. From Fontainebleau he was returned to his depot in the beginning of November, but, complaining of his left eye, he was sent to the ophthalmic centre of the 18th Region on Dec. 7.

*Condition.*—The bullet has penetrated the lower margin of the left orbit at about a centimetre from the inner canthus, lacerating the lower eyelid. The aperture of exit was found in the left malar bone, a little in front of the left tempero-malar articulation (Fig. 18).

V. has had no surgical interference. The wound is quite cicatrised. From Oct. 12, the visual acuity of the left eye has gradually diminished, until on the day of our examination it was—

L. E. V = 1/50, not improved by glasses.

The ophthalmoscopic examination (Plate VI, Fig. 1) shows a retinal detachment in the lower part, reaching

nearly up to the macular region. There are some floating opacities in the vitreous. It is probable that the bullet in its course has brushed against the lower part of the globe, without leaving any trace on the sclerotic; there is laceration of the retina and choroid extending to the macular region (contact lesion). (Plate VI, Fig. 1.)

The right eye is normal :—

R. E.. with $-1$ D sph., V $= 9/10$.

There is, in addition, anæsthesia of the left infra-orbital nerves (left half of the upper lip and left incisors).

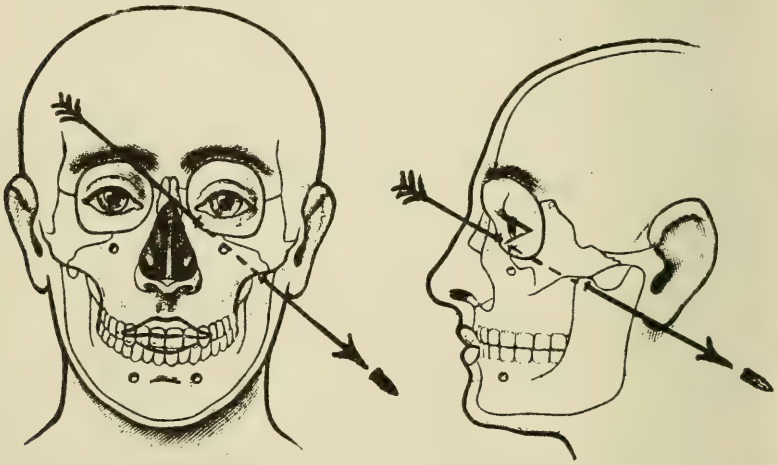


Fig. 18.

In spite of the orthodox treatment for retinal detachment, V. was discharged on Feb. 14, not improved.

**Bullet wound of face ; fracture of left inferior orbital margin ; detachment of retina, L. E.** (Case 17.)

A. J., Infantry, bullet wound, Sep. 9, 1914, left facial region. Dazed by the blow, J. noticed immediate and complete loss of vision of the left eye, accompanying profuse hæmorrhage in the inferior conjunctival cul-de-sac. Admitted Sep. 14, 1914.

*Examination.*—At the ambulance of Saintoing, three injuries were noted : one by the left lower lid, one in the left parotid region, the third on the left shoulder (Fig. 19).

These three wounds correspond to the course of the

same bullet, which entered at 1 cm. from the external angle of the orbit, perforating the lower eyelid, of which it divided the free border, fracturing the orbital margin. At this point the ocular conjunctiva and the sclerotic have been slightly wounded. The projectile emerged in the parotid region and wounded the shoulder at the end of its course. Radiography confirms the presence of a loss of bony substance from the inferior orbital margin, the crushing of the malar bone, and between them a line of fracture in the zygomatic arch (Fig. 19).

The pupil of the left is deformed; dilated below, in the direction of the scleral wound. The tension of the eye is

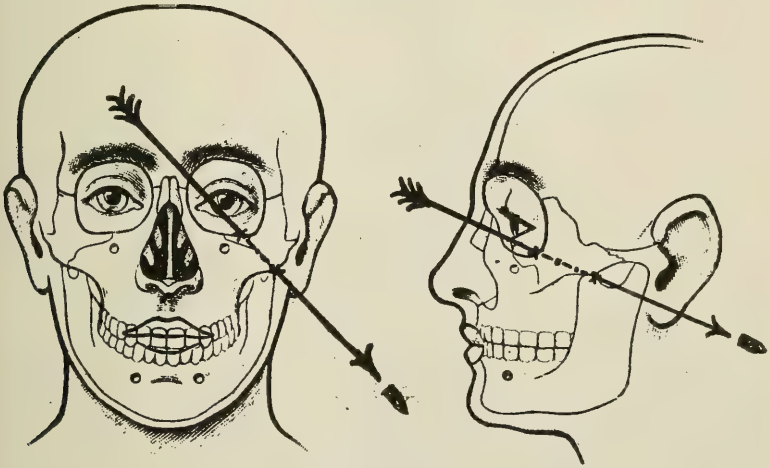


FIG. 19.

reduced (T. — 1). The ophthalmoscope discloses a very extensive retinal detachment (contact lesion).

This detachment is situated on the side of the scleral wound, near the aperture of entrance of the projectile.

The acuity of this eye is 1/100, the macular region being involved in the retinal detachment.

The right eye is normal.

Usual treatment for retinal detachment (compression bandage, atropine, sub-conjunctival injection of NaCl, rest in dorsal decubitus).

On leaving hospital, Dec. 12, 1914, no apparent improvement had been produced; persistence of detachment.

L. E. V = 1/100.

**Fracture of the left orbit by rifle bullet; rupture of choroid.** (Case 18.)

A. D., Infantry, wounded Sep. 15, 1914, at S.; under treatment till Nov. 23. Admitted Dec. 30 for visual trouble in the left eye.

*Condition.*—The bullet entered under the left eye, below a line dropped vertically from the external corneal margin. There is no trace of penetration upon the skin of the eyelid, but a small scar of the conjunctiva with slight symblepharon indicates the orifice of entry. The aperture of exit is found under the left ear immediately behind

Fig. 20.

the ascending ràmus of the mandible and a finger's breadth above the angle of the same bone (Fig. 20).

Radiography shows no bony lesions, although there was a fracture of the orbital floor.

In the period immediately following the injury he had fairly free hæmorrhage from the conjunctiva as well as from the mouth.

Sensation is preserved in the region supplied by the superior and inferior maxillary nerves; the malar region and the left cheek present evident signs of inflammation; the region is a little tense, red and painful.

The vision of the left eye is quantitative. After dilatation by atropine, no lesions of the anterior segment are

seen. The bullet has grazed the sclerotic. Transparent media normal. The deep membranes are the seat of very serious damage: optic disc softened in outline, peripapillary and macular pigmentation (concussion lesion), and pigmentation also in the lower part of the fundus. In this region an arciform choroidal laceration is also seen (contact lesion).

The right eye is normal. Visual field intact.

R. E. V = 1.

Discharged Feb. 1915, with the ophthalmoscopic appearance in the left eye unchanged.

L. E. V = Quantitative.

*We come now to the second category of cases, that of fractures of the orbit with preservation of the eye and the presence of a retained foreign body.*

## Second Category

**Fracture of right orbit; intra-orbital foreign body, macular choroido-retinitis.** (Case 19.)

C. D., Infantry, wounded at C., Oct. 21, 1914, by shell fragment in the right temporal region. From A. viâ Pau; admitted Dec. 12, 1914.

The aperture of entry of the projectile is found in the right temporal region. A cicatrix is situated a finger's breadth in front of and above the insertion of the ear. Radiogram shows a large foreign body in the orbital cavity, very near the posterior pole of the eyeball. The direction followed by this foreign body appears to have been from without inwards and behind forwards, penetrating the orbit through the great wing of the sphenoid (Fig. 21).

Severe orbital inflammation with exophthalmos followed the injury, but there is no trace of this at the time of examination.

The movements of the extrinsic muscles are preserved, with the exception of those which concern the paralysed levator palpebræ (ptosis of the upper eyelid).

The anterior segment and the transparent media of the right eye are in good condition, but the deep membranes

are seriously affected. There is cicatricial and pigmentary degeneration near the macula and in the outer equatorial region. Some tracts of proliferating retinitis cover in places these atrophic patches (organised hæmorrhage of the choroid with retinal lacerations).

R. E. V = 0.

L. E., with + 1 D sph. ⊂ − 2·5 D cyl., axis 0°. V = 9/10.

Jan. 21, 1915, Krönlein's operation, following the orthodox procedure, readily permitted the extraction of a fragment of shell, with irregular outline, 1 cm. long by

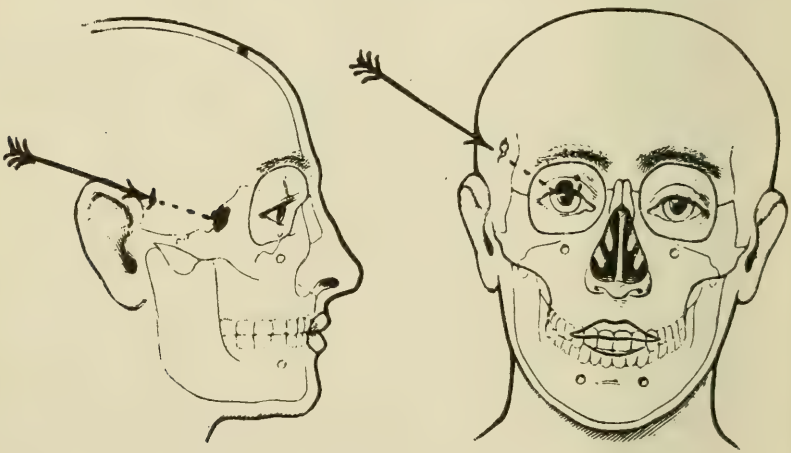


Fig. 21.

3 to 4 cm. wide, which was found behind the eyeball, against the optic nerve, inside the cone of the recti muscles.

Post-operative conditions normal; healing *per primam*.

D. left hospital Feb. 20, 1915, for discharge. He returned May 25, 1916, complaining of much pain behind the eye, and exhibiting slight blepharospasm. A new radiogram showed small fragments of shell disseminated in the fat of the orbit. The patient insisted upon their removal; a second operation, with turning back of the external orbital wall, was performed June 13; powdered fragments were extracted, no foreign body of any size being evident. Healing was rapid; relief was obtained from the symptoms, which were largely subjective. When

he went out, July 20, there was no change in the condition of the eyeball.

**Fracture of the superior-external margin of the right orbit; intra-orbital foreign body; extensive choroido-retinitis, R. E.** (Case 20.)

R., Captain, Infantry, wounded Sep. 25, 1915, by shell in the right orbital region; admitted three days later.

*Condition.*—The shell-fragment has penetrated the right upper eyelid, fracturing the upper and outer margin of the orbit. There is a deep notch in the bone, into which the tip of the index finger can be introduced (Fig. 22).

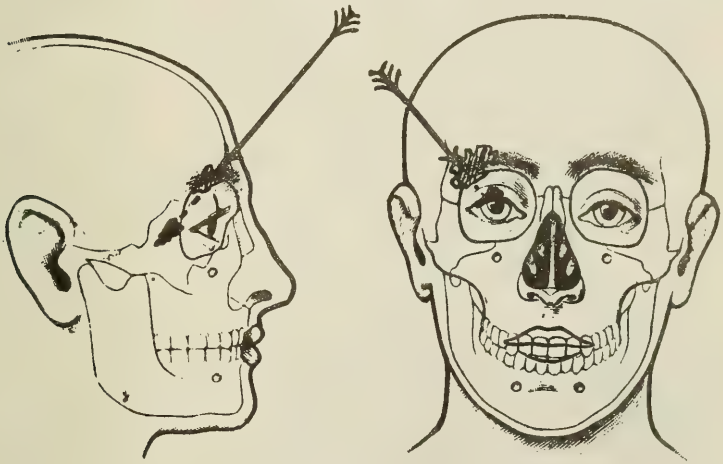


Fig. 22.

Almost complete ptosis of the upper eyelid is present; there is very pronounced exophthalmos, not reducible, probably due to an intra-orbital hæmatoma.

The pupil is dilated to the maximum owing to paralysis of the sphincter iridis. There is no effusion into the vitreous; the ophthalmoscope reveals a disc with softened contour, seen as though through a mist. In the macular region is a large hæmorrhage, which is continuous above and to the outer side with a choroidal hæmorrhage, resulting from rupture of this membrane.

R. E. $V = 0$. L. E. $V = 10/10$.

Radiography demonstrates the situation of the projectile

(Fig. 23); a voluminous shell-fragment has pierced the muscular cone, injuring the right external rectus and coming to rest behind the posterior pole of the eyeball which it has probably bruised directly.

Oct. 4, 1915, Krönlein's operation: after a curvilinear incision of the integuments external to the orbit, the outer orbital wall was raised by the gouge. A probe introduced in the track followed by the projectile allowed it to be felt and extracted.

Recovery from the operation was delayed by reason of several complications.

Fig. 23.

(1) A neuro-paralytic keratitis occurred, which was very long in healing, and complete recovery was only obtained by prolonged occlusion of the globe. A slight nebula remained when the patient was discharged.

(2) The breach in the orbital bones was the seat of suppurative osteitis, resulting in a sinus, which lasted till June, 1916, and was only cured by a further operation, in which a small fragment of shell and a splinter of bone were extracted.

On leaving hospital Aug. 4, 1916, the exophthalmos was not entirely reduced, but the upper eyelid had recovered

its mobility. There was complete paralysis of the right external rectus. Optic disc still a little blurred; large patches of post-hæmorrhagic atrophic and pigmentary choroido-retinitis in the macular region, above, to the outer side, and below.

R. E. V = 1/100.
L. E. V = 10/10.

**Fracture of left orbit; intra-orbital, fragment of bullet; optic atrophy and atrophic and pigmentary choroido-retinitis.** (Case 21.)

B., Adjutant, Curaissiers, wounded June 21, 1916, at

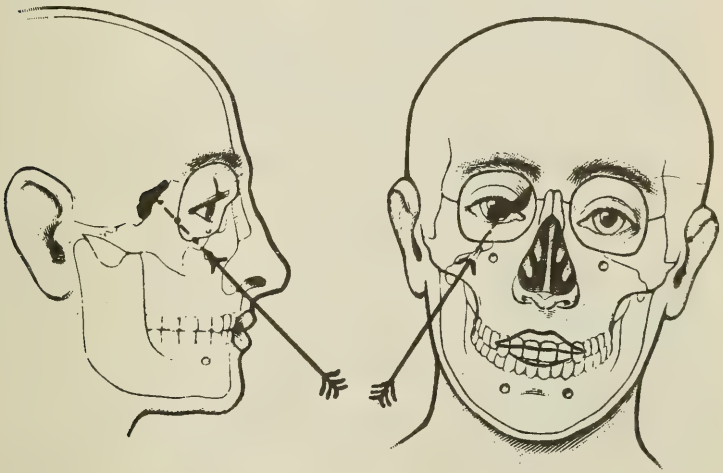


Fig. 24.

M., by a bullet in right orbital region. Was first at Ch. Admitted July 18, 1916.

The bullet has entered by the lower eyelid at 1½ cm. from the free border. It has fractured the inferior orbital margin, where, on palpation, a deep notch is felt. Radiography indicates the presence of the foreign body in the orbit, situated in the posterior part, near the apex and close to the roof (Fig. 24).

In the period immediately following the injury a considerable amount of exophthalmos was produced by the effusion of blood and inflammatory exudates. On July 18 this exophthalmos had almost disappeared. Some filaments

of the third nerve have been involved; the pupil is moderately dilated and immobile; the eye is divergent, owing to paralysis of the nerve to the right internal rectus.

Externally the eyeball is normal; transparent media intact.

Disc atrophic, with traces of old perineuritis.

The posterior pole, in the macular and perimacular zones, is the seat of numerous patches of cicatricial and pigmented choroido-retinitis. Vision reduced to simple perception of light. The left eye is normal.

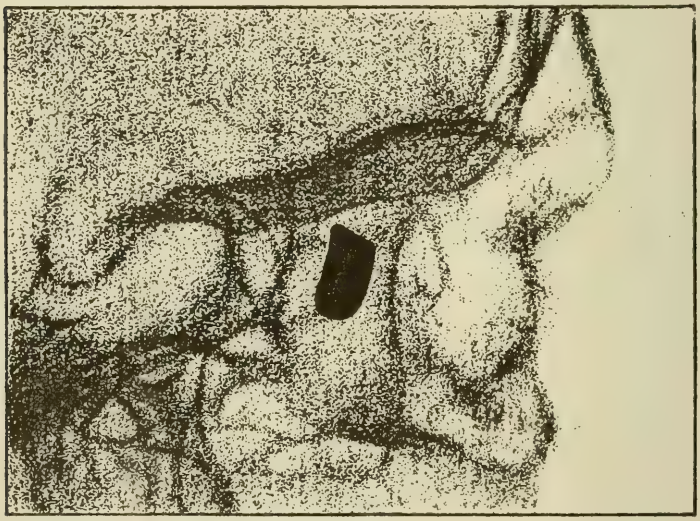


Fig 25.

July 25, Krönlein's operation. After resection of the orbital wall and section of the external rectus muscle the fibrous track resulting from the passage of the foreign body was reached. It was found at the apex of the orbit, near the sphenoidal fissure (Fig. 25).

The copper sheath of a bullet, greatly distorted, was extracted without difficulty. Post-operative progress normal. There remains only a slight paresis of the external rectus muscle, in a fair way to disappear. The exophthalmos, which reappeared after the surgical interference, passed away in eight or ten days.

Sep. 7, 1916, B. left for three months' sick leave.

**Fracture of left orbit by shrapnell ball ; optic atrophy.**
(Case 22.)

L. T., Infantry, wounded Sep. 16, at V. Was at Fimes two days later, and then at Casteljaloux. Sent on as convalescent, without any surgical interference, he noticed a rapid diminution of vision in the left eye, and was admitted Nov. 26, 1914.

*Condition.*—At the level of the left frontal sinus there is a cicatrix about 1½ cm. above the internal superior angle of the orbit. The base of the frontal sinus has probably been crushed in.

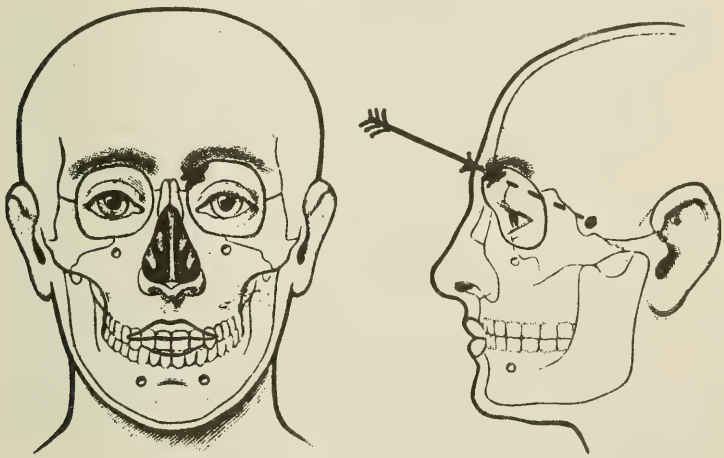


Fig. 26.

The left eye is slightly divergent, owing to paresis of the internal rectus, very faintly marked. The pupil reacts very feebly to its natural stimuli. The ocular media are normal, but the optic disc is in a fair way towards white atrophy, primary, not post-neuritic.

L. E. V = 1/30.

The visual field is concentrically contracted; blue and green are not perceived.

Radiography shows the presence of a shrapnel ball at the apex of the orbit.

R. E. normal. V = 10/10.

Dec. 3, 1914, the projectile was extracted by a curvilinear incision, situated above and to the inner side of the lacrymal sac. It was found in a bony mass in the wall at the apex; extraction difficult because of the tenacious adherence of the newly formed tissue.

Post-operative progress normal.

On discharge, Jan. 17, 1915, recovery was complete, but the optic atrophy had progressed. The pallor of the disc has increased and the visual acuity is scarcely 1/200.

In April, 1916, L. E. V = 0.

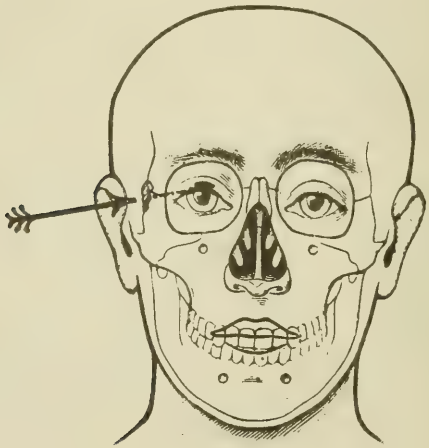


Fig. 27.

**Fracture of the right orbit; intra-orbital foreign body; extraction by Krönlein's method.** (Case 23.)

H. L., Zouaves, wound by revolver shot, June 9, 1914. The shot had penetrated the superior external region of the right orbit; the size of the projectile was 8 mm. Immediate loss of consciousness, lasting about half an hour; the sequelæ of the injury were of the simplest and only diplopia remained, due to paralysis of the external rectus.

L., by acquiring the habit of holding his head in an appropriate position, succeeded in suppressing the diplopia, and went on active service for eight months. In Nov. 1915, suffering from violent pains in the head, he was admitted June 1, 1916 (Fig. 27).

*Condition* —In the supero-external and lateral region of

the right orbit is a cicatrix, the aperture of entry of the projectile. This scar is $1\frac{1}{2}$ cm. behind the outer limit of the eyebrow. The bullet, following a horizontal course from without inwards, has perforated the external orbital wall behind the eyeball and come to rest in the muscular cone at a distance of $1\frac{1}{2}$ cm. from the posterior pole of the eye, in contact with the optic nerve, which has not been injured (Fig. 28).

The right eyeball is normal. The ocular media are

Fig. 28.

quite transparent; the disc presents no sign of atrophy. Visual acuity = 10/10.

The external rectus muscle is slightly paralysed, having probably been perforated by the bullet.

June 10, 1916, Krönlein's operation with large curvilinear incision of the integuments over the external orbital wall The projectile was found in the middle of the four recti muscles, ensheathed in very dense fibrous tissue. Extraction was easy. Post-operative conditions normal. There remains only marked paralysis of the external rectus muscle, accentuating the diplopia of which the patient previously complained.

Sep. 14, 1916, tenotomy of the internal rectus and advancement of the external rectus were performed. These operations, combined with fusion exercises with the diploscope, brought about a great improvement in the diplopia, which still exists to a slight extent in the region of action of the right external rectus muscle.

R. E. V = 10/10.

**Shell wound with intra-orbital foreign body : fracture of the external wall of the left orbit ; multiple retinal detachments.** (Case 24.)

J. R., Private, wounded at V., March 13, 1916; reached Bordeaux March 18.

*Condition.*—A Y-shaped cicatrix is seen in the left orbito-frontal region, the fork directed towards the ear, extending from the centre of the left eyebrow to the middle of the temporal fossa (Fig. 29).

The injury at its two extremities involved the soft parts only. In its median portion the scar is adherent to the superciliary ridge, in a bony depression corresponding to the external margin of the orbit, which has been bevelled off by the projectile.

Radiography discloses a loss of substance in the external and superior orbital region, a zone from which several splinters have been extracted, as well as a fragment of shell, which was intra-orbital and situated above the eyeball.

The violent contusion had caused profuse hæmorrhage into the vitreous of the left eye, which during the first months of his stay in hospital did not allow of examination of the fundus. Tension reduced (T — 2).

L. E. V = 0.

May 25, 1916, the ophthalmoscope showed almost complete disappearance of the hæmorrhage into the vitreous, only some floating opacities remaining. There are large retinal detachments, one peripheral in the nasal equatorial region, the other occupying the macular region and the temporal region (contact lesion). The disc is slightly pale (Fig. 30). Visual acuity 1/200.

This condition does not appear to be final, for traumatic

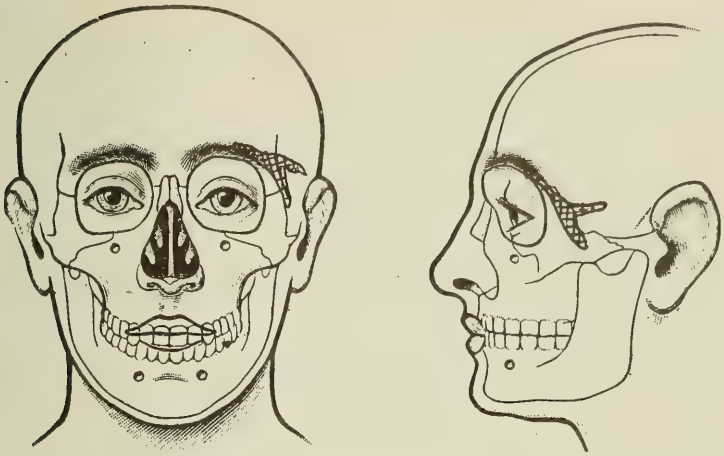


FIG. 29.

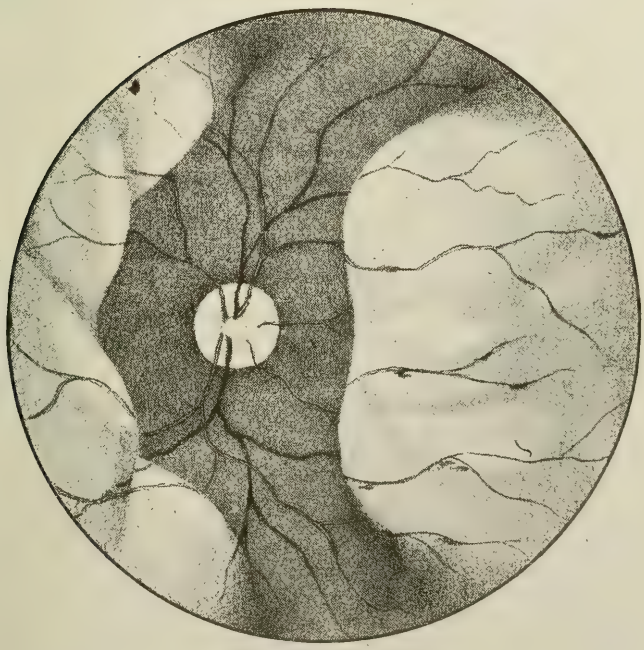


FIG. 30.

retinal detachments improve and disappear with the lapse of time.

R. E. normal. V = 10/10.

**Fracture of left orbit; intra-orbital foreign body; macular choroiditis.** (Case 25.)

J. H., Officer, Colonial Artillery; wounded Sep. 1, 1914, at A., by shell fragments, in left orbital region. At the Orleans hospital till Sep. 20, when he was returned to his depot. Complaining that he could not see, he was admitted Nov. 15, 1914.

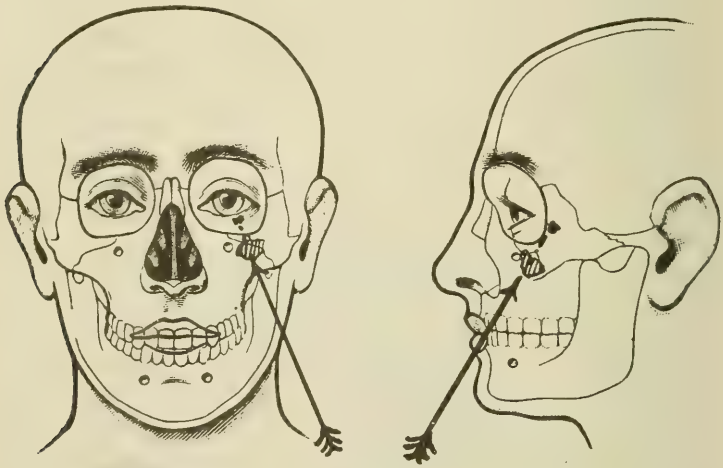


Fig. 31.

*Condition.*—H. presents a wound near the external canthus of the left eye. The projectile has penetrated the orbit, fracturing the infero-external margin, where there is a small cicatrix with symblepharon at the aperture of entry. Immediately following the injury considerable exophthalmos was produced by intra-orbital effusion of blood, of which no trace remains (Fig. 31).

There is no lesion of the appendages; the movements of the globe are well preserved; no affection of the anterior segment or the transparent media. With the ophthalmoscope, however, one notes a well-marked macular lesion, with a zone of atrophy, and below it a zone of pigmentation. Further, in the neighbourhood of the aperture of entry there is to be seen an extensive patch of atrophic

and pigmented choroido-retinitis, indicating that the shell fragment, in penetrating the orbit, has grazed the eyeball.

Perimetric examination reveals the existence of a central scotoma extending into the upper part of the visual field.

L. E., with + 0·50 D sph., V = Quantitative.
R. E. normal. V = 10/10.

Radiography shows two shell fragments. The more bulky seems to be in the antrum. The smaller is in the left orbit, behind the eyeball.

Nov. 22, 1914, the orbit was opened from the outer side, after a curvilinear incision, but without excision of bone. The eye, after section of the external rectus muscle, was hooked inwards; the portion of shell, encapsuled in fibrous scar-tissue, was readily removed.

Post-operative progress without inflammatory complications, but, shortly after, blepharospasm appeared, probably caused by irritation of the infra-orbital nerve, consecutive to the traumatism and the temporary sojourn in the region of the nerve of the foreign bodies which were now removed.

The nerve was resected in the orbit Dec. 15, 1914. Blepharospasm quickly disappeared, and H. was discharged Jan. 4, 1915, with the vision of the left eye unaltered.

## § II.—Pathology of the Visual Disorders

### First Group

The visual affections of the first group are explained by damage to sensory nerves (lacrymal, frontal), the various motor nerves, and by lesion of the optic nerve, the consequences of the propagation to these organs of fractures of the orbital vault, radiated or by contre-coup.

Atrophy of the optic nerve, following injury of the nerve, upon which many authors, and particularly Chauvel and Nimier have insisted, explains itself: it is not so easy to account for the trophic and sensory affections presented by the patients, particularly by the cases of enophthalmos. (Case 39 *et seq.*)

It is probable that in cases where enophthalmos has occurred the sympathetic nerve has been injured at its entry into the orbit or within the orbit itself. Section of the cervical sympathetic, or rather, the suppression of the action of this nerve, will explain enophthalmos satisfactorily. Laceration of the nerve filaments produces this result, but irritation, continued excitation of the same nerve filaments, also induces it, for the excitability of a nerve diminishes in proportion as the excitation is prolonged and increased in intensity, so that a very prolonged irritation amounts to the same as section—that is to say, to enophthalmos.

This enophthalmos is therefore equally well explained by complete laceration, section of the trophic nerve filaments, and by irritation of these nerve filaments prolonged over a long period; continued excitation, prolonged irritation, as well as laceration of the nerves, are themselves explained by radiation of the cranial fracture into the sphenoidal fissure.

### Second Group

The macular lesions we find in eyes which are to all appearance absolutely intact, disturbed at a distance by injury implicating the bony mass of the face, far from the orbit, result from the propagation of the vibratory concussion to the orbital contents by way of the fossa and the pterygo-maxillary fissure.

The eye is raised, shaken as a submerged boat would be when struck by a deep wave, attacking it from beneath. It is probable that this concussion of the whole mass of orbital fat, which is semi-fluid at the temperature of the body, is the cause of the ruptures produced in the deep membranes.

How is it that these injuries are often exclusively macular, and that when ruptures occur elsewhere the chief lesions are at the posterior pole? It is possible to explain such localisation: in the first place, by this fact, that the macular region is the most fragile, the most

sensitive to injury and to traumatism; in the second place, because the eye, tossed forward by the wave of oscillation which agitates the depths of the orbit behind the globe, is held back by the optic nerve firmly attached to the apex of the orbit.

This traction is exerted on the whole of the posterior pole, and hence localises ruptures and hæmorrhages to this region. Sometimes patients whose faces have been severely contused have lost central vision without the macula presenting any visible lesions. One must beware of concluding that this is due to malingering: central scotomata are quite well explained by the existence of disorders which are invisible by ophthalmoscopic examination.

### Third Group

The affections of the third group, which are consecutive to the depression, the impaction, more or less marked, of one of the walls of the orbit, are amenable to the same explanation, and one can understand that they may be even more marked than when the projectile has traversed the bony mass of the face without altering the conformation of the orbital cavity. Here it is the pillars and the sides, not the basement of the vault, which are assailed; it is easy to understand that the organs which are contained in the orbital cavity are more seriously affected by the injuries which crack or perforate the actual walls and pillars of the edifice.

In this third group there are macular lesions which are explicable by the mechanism we have explained above; but there are also vast choroidal lesions which are ruptures resulting from the violence transmitted by the fluid material. These latter lesions vary in degree according to the amount of depression of the orbital walls and the severity of the shock.

They are remarkable from the point of view of localisation by the fact that they are always situated on the side of the orbital fracture; the wave which jars the soft

parts starts from the site of the fracture and strikes the eye in front of it with a sharp blow, rupturing its membranes. It is agreed that the tearing affects first and foremost the choroid, which bleeds; the blood lifts up the retina and detaches it. When the latter membrane is itself torn a choroido-retinitis proliferans is produced, a condition of which we have seen a large number of typical examples.

Summing up, in the third group we find—

(1) a definite macular lesion; (2) a choroidal rupture, most frequent; sometimes choroidal and retinal ruptures, on the side of the fractured orbital wall.

### Fourth Group

When the projectile has traversed the orbit without touching the eye it is obvious that very different results may be produced according to the organs—muscles, motor and sensory nerves, etc.—which are injured. The same bullet may traverse both orbits and sever both optic nerves behind the globe. We have noted several cases of this nature. When the optic nerve has been divided, or when it has been severely bruised, much damage is done at the posterior pole owing to the traction exerted on the eye by the nerve. The force, before dividing and bruising the nerve, thrusts it violently forwards in the direction in which the projectile is travelling, and tends to tear it from its insertion in the eyeball.

Cases 9 and 10 (Plate III, Fig. 1; Fig, 35) are examples of this type. The pathogenesis of such lesions presents no obscurity.

Lacerations of motor and sensory nerves and of muscles can be readily explained; there is no need to stop to consider them.

### Fifth Group

The fifth group of ocular disorders comprises cases of direct contusion of the globe, without rupture of its

walls, by a projectile which passes it tangentially and to some extent grazes it.

Under these conditions there are always lesions exactly where the missile has touched the eye. They are contact lesions, and are of the nature of ruptures of the choroid and retina.

Often the two membranes are simultaneously torn, owing to the violence of the shock; the destruction is very great, has its point of election at the point touched, and is readily propagated to the macular region. The macula is in consequence often implicated under these circumstances, but not as an isolated and separate lesion. In such cases the eyeball may be disorganised without being ruptured. Obviously, if the missile passes too near the eye it destroys it by making it burst, but we are not speaking of ruptures of the globe. Our fifth group comprises the cases in which the eye is directly contused by a projectile, which grazes it in passing, without rupturing it. It is evident that under such circumstances we must expect to find the greatest destruction in the deep membranes. From the site of contusion lacerations spread out into all directions, especially involving the posterior pole, which is always very sensitive to injury.

The visual troubles which are produced in the cases in which fracture of the orbit is complicated by the presence of a foreign body are explained in the same manner as in the cases belonging to the two last groups. It is needless to consider them further.

### § III.—Description of the Visual Defects

Such are, from the point of view of their mechanism, the affections of the visual apparatus which are caused by fractures of the orbit in which the eye is preserved.

We must now discuss each in turn, studying them in the following order:—

(A) *Nerve lesions:* 1st, motor; 2nd, sensory; 3rd, sympathetic; 4th, those of special sense.

(B) *Lesions of vessels:* Ophthalmic artery and vein; traumatic hæmorrhage into the orbit.

(C) *Lesions of the intrinsic and extrinsic muscles.*

(D) *Affections of the eyeball:* 1st, of the transparent media; cataracts, luxation of the lens: 2nd, of the membranes, (*a*) uveal tract; (*b*) retina, traumatic detachment.

(E) *Traumatic enophthalmos.*

We shall study these various disorders under their separate headings.

### A.—Lesions of Nerves: Motor, Sensory, Sympathetic, and of Special Sense

In order thoroughly to grasp the nervous affections which are brought about in the visual apparatus by injuries to the orbit it is necessary to bear in mind the sphenoidal fissure, which we represent here according to the recognised authorities.

No anatomical description will be given—the reading of the legend which accompanies the illustration will suffice to enable our readers to follow the demonstration of the cases we have observed.

It is easy to understand which nerve trunks will be most likely to be implicated by a fracture radiating into the roof of the orbit, or by a direct blow upon the wall of the orbit.

#### (1) Motor Nerves

The nerve most often injured is the oculo-motor (IIIrd); this paralysis is due in the majority of cases to a fracture of the superior wall of the sphenoidal fissure, particularly of the anterior clinoid process, on account of the relations of the nerve with this process. Frequently there co-exists, for the same reason, a traumatic amaurosis. The same reasoning does not apply to the sixth nerve, which is the farthest removed from the superior wall of the sphenoidal fissure; paralysis of this nerve is usually due to fracture of the base.

Paralysis of the fourth nerve may be equally due to a fracture of the roof of the sphenoidal fissure, for this

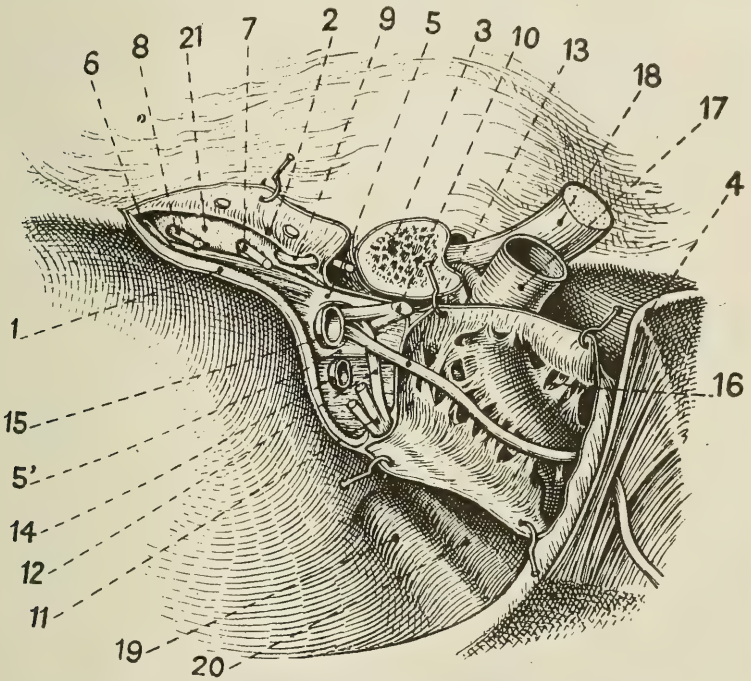



FIG. 32.—The sphenoidal fissure and the organs which pass through it (after Testut and Jacob).

The sphenoidal fissure is viewed from the interior of the cranium. The periosteum and the dura mater which close it have been incised and the flaps hooked back. The cavernous sinus has been opened.

1. Inferior border of the sphenoidal fissure. 2. Superior border. 3. Anterior clinoid process divided at its base. 4. Posterior clinoid process. 5, 5'. Ring of Zinn. 6. External rectus muscle. 7. Lacrymal nerve. 8. Frontal nerve. 9. Pathetic (fourth or trochlear). 10. Motor oculi (third). 11. Common trunk of lacrymal and frontal nerves. 12. Nasal nerve. 13. External motor oculi (sixth). 14. Inferior ophthalmic vein. 15. Inferior vein. 16. Cavernous sinus. 17. Internal carotid. 18. Optic nerve. 19. Superior maxillary nerve. 20. Ophthalmic of Willis (first division of the fifth). 21. Orbital fatty tissue.

nerve is quite close to it; paralysis of the ophthalmic branch of the trigeminal may be due to the same cause.

When the whole of the trigeminal is implicated the explanation of its paralysis must be sought in a fracture of the apex of the petrous portion of the temporal bone. These are the conclusions to which FERRON arrived in an excellent Thesis on this subject (Lyons, 1901). This author, moreover, very justly remarks that paralysis of the nerves of the orbit, when they have not an orbital cause, are symptoms of fracture of the base of the cranium.

This is not the place to demonstrate the mechanism by which fractures of the cranium are propagated to the orbital vault. We refer readers to the authorities on this question, especially to the article "Orbite" by ROLLET, in *l'Encyclopédie d'Ophtalmologie*" (Vol. VIII); in order to comprehend the cause of the nerve lesions which we have observed in orbital fractures it will be sufficient for us to recall the anatomical data given in Fig. 32.

We have seen four cases of paralysis of the third nerve, two of paralysis of the sixth, one of paralysis of the fourth. We have noted another disturbance in the action of the superior oblique due to dislocation of the pulley of this muscle. When the sixth nerve is affected the cause is most frequently orbital; we have twice found paralysis of abduction after fractures by direct shock upon the temporal wall of the orbit.

### (2) SENSORY NERVE

The trigeminal, in fractures of the orbit, may be damaged not only in its first branch, the ophthalmic of WILLIS, but it is not uncommon to find that fracture of the floor of the orbit implicates the superior maxillary nerve, which is rarely divided, more often compressed. Anæsthesia in the corresponding region follows, and often too, signs of irritation, of which we have notes of two cases presenting an obstinate blepharospasm which yielded only to surgical interference. In the first case a piece of shell, penetrating 1 cm. below the inferior orbital margin, probably damaged the

infra-orbital nerve before coming to rest in the orbit, from which we extracted it. The second patient was struck by a projectile which smashed in the orbital floor without penetrating the tissues. The blepharospasm was confined to the lower eyelid. We performed on both subjects resection of the nerve trunk in the orbit, according to the orthodox procedure, and the contractions of the lids rapidly disappeared in the period following the surgical interference.

### (3) Sympathetic Nerve

Branches of the ophthalmic nerve of Willis may be injured and with them the vaso-motor filaments they contain, and it is not rare, in addition to corneal anæsthesia, to see neuro-paralytic troubles, the more readily explicable because the sympathetic filaments may have been equally affected by the traumatism.

It is not impossible, however, for the injury to implicate all the nerves at the same time, with the exception of the sympathetic, and we have met with an interesting case which merits consideration from this point of view.

**Fracture of left orbit; total ophthalmoplegia; optic atrophy L. E.** (Case 26.)

J. A., Infantry, wounded Sep. 30, 1914, near R. At Chalons till Dec. 4; admitted Dec. 8.

*Condition.*—Struck by shrapnel ball in the left temporo-parietal region, two fingers' breadth above the insertion of the ear, three fingers' breadth behind the extremity of the eyebrow.

Radiography in profile shows the projectile situated immediately in front of the sella turcica; and the radiogram, taken from in front, indicates its presence against the superior internal wall of the left orbit. It has therefore in its course involved the apex of the orbit slightly in front of the sphenoidal fissure, which it has doubtless smashed in (Figs. 33 and 34).

The upper eyelid is in a condition of complete ptosis. The eyeball is quite immobile; all the extrinsic muscles

are paralysed. There is no exophthalmos; but the eye is slightly deviated to the outer side, in the orbital axis.

The anterior segment is normal; the pupil, very dilated, reacts neither directly nor consensually (Fig. 34).

The anæsthesia extends over the whole of the region supplied by the trigeminal, total for the ophthalmic branch of WILLIS, partial so far as concerns the dental and infra-orbital branches.

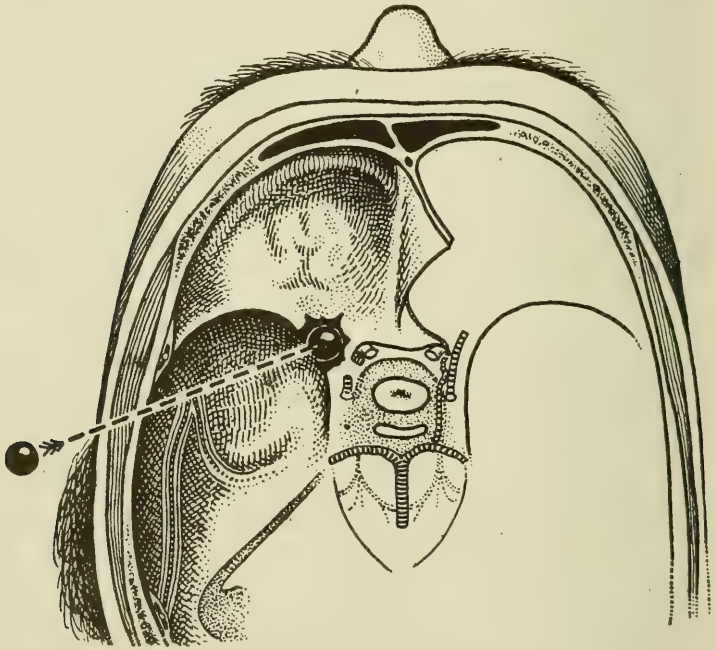


FIG. 33.

Ophthalmoscopic examination reveals white atrophy of the optic nerve; the veins are normal, but the arteries are very slender.

L. E. $V = 0$.

The right eye is intact. No lesion of the transparent media or deep membranes. The visual field is normal.

R. E., with + 1 D sph., $V = 1$.

Taking into consideration the very deep situation of the projectile, the dangers inseparable from its extraction,

and the perfect tolerance for it displayed by the brain, surgical interference was postponed, and the patient left hospital March 9, 1915.

In this curious case, all the nerves of the eye without exception were implicated, and still the eye survived. It only presented neuro-paralytic phenomena; the fact must be explained by preservation of the ophthalmic

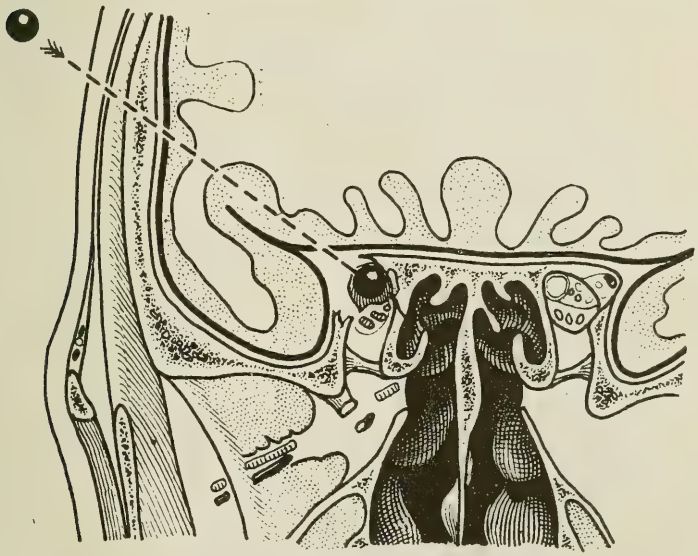


Fig. 34.

ganglion, that tiny brain of the eye, which continued to control its nutrition.

Of all the lesions presented by the nervous apparatus of the eye those of the optic nerve must be dealt with at greatest length.

### (4) Lesions of the Optic Nerve

It is convenient to divide the traumatic lesions of the optic nerve resulting from injuries of war into three classes, according to localisation: (*a*) the intra-ocular portion; (*b*) the retrobulbar portion, which

contains the central artery and veins; (*c*) the non-vascular portion, which extends from the optic foramen to the entrance of the central artery and vein.

(*a*) *Intra-ocular portion; traumatic lesions of the papilla.*—These are the injuries which we find when the papilla has been torn out by a sudden stretching of the optic nerve. A blunt instrument or a metallic

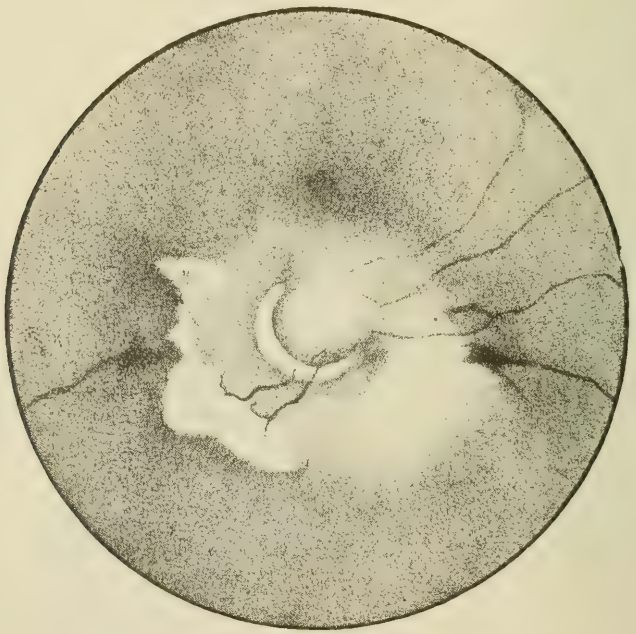


Fig. 35.—Avulsion of the optic nerve.

fragment sharply pushes aside the nerve, tears it out, so to speak, and detaches it from its insertion into the globe. We have observed several examples of this condition in which the ophthalmoscopic appearance was similar to that which Gonin gives in the *Encyclopédie française* (Vol. VII, p. 534).

Free hæmorrhage at once follows the avulsion, and when the blood has absorbed we see the remnants of torn vessels and sometimes a deep excavation due to

rupture of the sclerotic. In a case of Pagenstecher's the nerve had been absolutely torn out from the scleral ring, and the retina had been dragged into the opening.

In this manner a traumatic excavation of the disc is produced, a sort of coloboma or surgical conus, much more pronounced than the glaucomatous excavation. GONIN quotes a case of BIRCH-HIRSCHFELD'S in which the difference of level was 2 mm. This excavation may become filled with proliferating connective tissue, in the same manner as in retinitis proliferans.

Gunshot wounds of the temple in attempts at suicide have afforded opportunities for the study of this type of lesion, of which we have notes of several cases amongst our wounded (Fig. 35, and Plate III, Figs. 1 and 2). It will be understood how, besides total or sub-total avulsion of the papilla, partial luxations, more or less pronounced, may occur, and between the most complete total detachment and the most moderate partial luxation it is easy to conceive all the varieties which have been demonstrated at our centres of military ophthalmology.

(*b*) *Lesions of the nerve in the retrobulbar portion which contains the central artery and vein.*—A projectile entering the orbit immediately behind the eye may divide the nerve more or less completely, tearing it, and with it the vessels which it contains. In these cases an ischæmia of the central artery is caused, presenting the ophthalmoscopic picture of embolism. To produce this ophthalmoscopic appearance it is not even necessary that the nerve should be lacerated; it is sufficient that the artery should be torn, with or without the vein. HIRSCHBERG has reported a case of section of the optic nerve in which, in the course of two months, the retinal circulation became re-established at the same time as a visual acuity of 1/20. It is quite possible that in this case there was only a lesion of the central artery, and that the retinal circulation became restored

later by a collateral circulation between retinal arteries and those of the ciliary body; for anatomy demonstrates at the same time the difficulty, and the possibility, of the re-establishment of the retinal circulation by this mechanism.

The gravity of such a disaster does not need to be demonstrated. When the artery and the vein are lacerated the functions of the retina are abolished; and when the optic nerve is seriously contused the rupture of the nerve filaments adds an additional complication, and causes atrophy of the disc, a fatal consequence which also follows destruction of the vessels alone.

The condition is not so grave if the contusion of the nerve is so superficial as not to interfere with the circulation in the central artery and vein. It is known that the nerve can be pulled on fairly strongly without the vessels suffering; indeed, stretching of the optic nerve has been recommended in cases of atrophy by De Wecker, who hoped thus to restore the nutrition of the nerve by stimulating the circulation of blood in the vessels which it contains.

It is, however, rare for the optic nerve to be pulled on and bruised by a projectile without causing gross damage, and consecutive papillary atrophy is the ordinary result of traumatism. Moreover, when the foreign body is bulky, as in Case 20, at the same time as the optic nerve is bruised, the posterior pole is also the seat of grave lesions (profuse hæmorrhage in the macular region, and a veritable lake of blood in the choroid, resulting from the rupture of a vessel). Radiography and Krönlein's operation showed that in this case the projectile was behind the globe and in contact with the nerve.

(c) *Lesion of the nerve behind the site of entry of the vessels.*—In military surgery the optic nerve may be wounded directly by a penetrating foreign body, or indirectly by a fracture radiating towards the optic foramen, where a splinter may lacerate it as it passes through the foramen opticum.

(*d*) *Direct injuries.*—These occur after the entry into the orbit of foreign bodies, shrapnel, fragments of shell, etc.; at the same time as the injury to the optic nerve the projectile may have grazed and more or less bruised the eyeball, which may itself present direct lesions. It may happen that vision is only partially destroyed, and GONIN in his article in the *Encyclopédie française d'Ophtalmologie* (Vol. VII, p. 537) reports a case in which, after wound of the nerve by a fragment of lead, there was partial loss of vision; that is, a great exception to the rule that injury to the optic nerve by a projectile is followed sooner or later by complete atrophy of the nerve.

Such was our experience in a case in which the projectile, the sheathing of a bullet, was found after a Krönlein operation in the apex of the orbit, near the sphenoidal fissure (Case 21).

When the projectile is at the apex of the orbit, in contact with the nerve, in Cases 22 and 26, it may act by compression and bring about a simple primary white atrophy, *i. e.* not neuritic.

It may happen, further, that a large projectile enters the orbit, comes to rest within the muscular cone, without implicating the optic nerve, and leaving the eye with good vision. This happened in Case 23, where a shrapnel ball, following a horizontal course from without inwards, having perforated the external orbital wall behind the eyeball, came to rest in the cone of muscles $1\frac{1}{2}$ cm. from the posterior pole of the eye, at a very short distance from the optic nerve, which remained intact. When the intra-orbital foreign body is outside the muscular cone the optic nerve is much more likely to remain unharmed. This occurred in Case 20, where the shell fragment lodged above the globe and provoked, by direct contusion of the eyeball, serious damage in the deep membranes—hæmorrhage into the vitreous, choroidal rupture, retinal detachment.

(*e*) *Indirect injuries.*—These are consecutive to fractures. All ophthalmic surgeons who have experience

of industrial accidents know how frequently falls upon the head and fractures of the cranium are followed after a certain lapse of time by loss of vision on one side. Here we are dealing with those radiated fractures which, at the optic foramen and the sphenoidal fissure, lead to laceration of the vasculo-nervous bundle which represents the hilum of the orbit and the eye. It is now a long time since this anatomico-clinical theory, foreseen by some clinicians, was shown to be scientifically accurate by BERLIN. We have proved that in our cases these radiations were invariably due to injuries to the frontal bone.

Lesion of the optic nerve, moreover, may not be very serious, and absolute blindness does not always result. WILBRAND and SAENGER, out of 100 cases of unilateral optic lesions, following cranial traumatism, have recorded 50 cases of complete and permanent blindness, 4 cases of total blindness at the outset, which terminated by complete recovery, 17 by partial recovery with limitation of the visual field, and 24 cases in which the lesion of the nerve had been partial from the outset.

From this it follows that one must be very circumspect as to the prognosis of such lesions, especially when they affect soldiers, candidates for discharge and a pension, whose visual acuity is not always easy to determine. We have observed a recent example (Case 60), in which, after severe injury to the left temporal region, which demanded trephining, the visual acuity, by reason probably of lesion of the left optic nerve, had fallen to 1/10. The patient obstinately kept to this figure, when, by the test of the reversed image, we had convinced ourselves that it was at least 1/3.

In certain cases the traumatism is shown only by a central scotoma. In this case it is well to think of compression of the optic nerve; this compression affects by preference the macular bundle whose delicate functions are readily deranged. Under such circumstances probably there is swelling of the optic nerve,

or compression by a profuse intra-orbital hæmorrhage, or still more likely, hæmorrhage into the sheath.

This condition of hæmotoma in the tunics of the optic nerve merits particular attention.

### Hæmatoma of the Sheaths of the Optic Nerve

Is effusion of blood into the sheaths of the optic nerve common after the orbit has been traversed by a projectile?

Is the classic opthalmoscopic picture, consisting of a brownish peri-papillary margin, often observed? These are the two questions which the military ophthalmic surgeon must put to himself, and our answers must be in accord with the observed facts and recorded cases.

A few words in the first place to set the question fairly before us.

Magnus and De Wecker and several others have sought to define precisely the clinical and anatomical signs of hæmorrhage into the sheaths of the optic nerve.

Magnus set himself to demonstrate: (1 that hæmorrhage of the nerve is followed in a few hours by characteristic peri-papillary and macular changes; (2) that the hæmorrhage is accompanied by a narrowing, more or less marked, of the arteries, with hyperæmia of the veins; (3) that the visual field becomes obscured from the centre towards the periphery in hæmorrhage of the nerve.

To all these signs De Wecker adds another which he considers to be very important, viz. the appearance of a peri-papillary flame-shaped hæmorrhage, and of minute hæmorrhages surrounding the macula. He agrees, therefore, that effusions of blood in the optic nerve extend to the retina, and he even believes that certain hæmorrhages of the vitreous come from the vaginal spaces of the optic nerve.

Rollet and Abadie support this view; they describe a peri-papillary layer of blood quite visible

with the ophthalmoscope, and we find similar assertions in the treatises of SCHWEIGGER and GREEFF, of DIMMER, in SCHMIDT-RIMPLER'S manual, etc.

GONIN, who has written a very interesting work on this subject, develops an opinion contrary to that of MAGNUS and DE WECKER.

He is of opinion that there is no case which supports these doctrines concerning the ophthalmoscopic signs of apoplexy of the optic nerve. He says that there is not a single case on record of this "sudden blindness which, after presenting the picture of retinal ischæmia, was proved by autopsy to be due to an effusion into the sheaths or the substance of the nerve; on the other hand, there is not a single case of proved vaginal apoplexy which manifested the ophthalmoscopic signs of obstruction of a central artery."

Following the same sequence of ideas, and in confirmation of GONIN'S opinion, particular attention should be given to a remarkable work by DUPUY-DUTEMPS upon hæmatoma of the sheaths of the optic nerve in meningeal hæmorrhage. In an historical essay of the highest value this author shows that hæmorrhage of the optic nerve of traumatic origin is due to the penetration into the vaginal cavity of blood effused in the cranial sub-arachnoid space.

Histological study in a first case proves that the intra-vaginal hæmatoma does not extend towards the globe beyond the anterior extremity of the cavity and does not cross the scleral barrier; blood does not penetrate farther along the trunk of the optic nerve. There were certainly in this case small islets of retinal hæmorrhage, but these hæmorrhages have no direct relation with the vaginal hæmatoma of the nerve of special sense of the eye.

In a second case, having to do with a spontaneous meningeal hæmorrhage, DUPUY-DUTEMPS has demonstrated the same precise anatomical facts; the hæmorrhage does not extend as far as the disc; it infiltrates the innermost fibrous bundles of the dural sheath, particularly as far as the central vessels, which it

surrounds with a continuous mantle. In these cases the ophthalmoscopic signs are not as MAGNUS, DE WECKER and the classic authorities in general have taught, those of retinal ischæmia, but simply œdema of the papilla, with dilatation of the veins, and retinal hæmorrhages which have arisen *in situ*, consecutive to difficulties in the circulation due to the compression of the central vessels.

Such are the older teachings (MAGNUS, DE WECKER, etc.) and the recent opinions (GONIN, DUPUY-DUTEMPS) concerning hæmatoma of the optic nerve. We make no pretension of writing an historical essay, however incomplete, on the question, our object being merely to contrast the two points of view, which are still *sub judice*.

It now remains only for us to state on which side we should range ourselves, after having observed a considerable number of grave injuries of the optic nerve which should certainly have been frequently accompanied by hæmorrhage into the sheaths. We say, modestly, " which should have been accompanied," because, as a matter of fact, we have not any histological examinations to throw into the arena of discussion, not having had, fortunately, to make autopsies on our wounded. It is, however, impossible that the optic nerves, bruised, lacerated by bullets, or shrapnel balls, or irregular shell fragments, which we have observed, should not have bled often into their sheaths, and, clinically speaking, we have many times been confronted with traumatic vaginal hæmatomata of the optic nerve.

We owe it to the truth to state that we have not found on a single occasion the ophthalmoscopic signs and clinical symptoms of retinal ischæmia, and that we have never observed the papillary effusion of blood upon which ABADIE has insisted. In civil ophthalmology it has been the same; after having examined, as happens to all ophthalmic surgeons in extensive practice, many injured persons who have suddenly lost the sight of one or both eyes, we have never seen

the blood well up into the eye from the sheaths of the optic nerve, and we have the impression that GONIN and DUPUY-DUTEMPS are right. Most certainly the anatomical researches made, notably by the latter author, count in the debate for much more than our impressions as clinicians, but it is not permissible to omit to state that our clinical observations and their pathological anatomy are in perfect accord.

One point, however, merits to be brought into relief. I have not found peri-papillary hæmatomata and intra-ocular effusions of blood consecutive to hæmorrhages of the optic nerve, but I have sometimes seen, a considerable time after the traumatism, the brownish pigmented ring of which the classic authorities speak.

I have observed it recently in patients suffering from serious injuries which caused at the outset, without any lesion, a complete loss of central visual acuity; vision became re-established gradually in the course of time.

**Fracture of the right superior orbital margin; hæmorrhage into the sheaths of the optic nerve.** (Case 27.)

P., Infantry, wounded Jan. 10, 1916, by shell-fragments, of which one had caused a slight depression of the right superior orbital margin, from which it had been extracted. According to the patient's story the shell burst at a distance of about 1 metre, and the explosion was followed by total loss of vision of both eyes. The sight of the left eye returned twelve hours later, but the right eye only commenced to perceive light three weeks after the injury.

On his arrival acuity was as follows—

R. E. Perception of light.
L. E. V = 3/10.

No lesion of transparent media nor of deep membranes. The visual field, taken Jan. 19, shows irregular contours on the left side, with peripheral contraction and a semi-annular para-central scotoma.

*Condition.*—March 3, 1916, the pupil reacted feebly to light. There is slight inequality of pupils.

The accommodation reflex exists, but is enfeebled; consensual more energetic in the L. E.

March 3.—R. E. V = 1/20.
L. E. V = 4/10.

On March 6 there is reported for the first time, on the temporal border of both discs, a blackish-red pigmentation, bordering the scleral ring, leading one to think of a hæmorrhage of the sheaths; these pari-papillary half-rings can only be blood or blood débris, which has taken several months to arrive at the disc.

L. E. V = 4/10.
R. E. V = 5/10.

The visual field taken at this date shows a concentric shrinking without central scotoma.

March 27, 1916, R. and L. E. Reflexes normal, no lesions of the fundus, except the pigmentation reported on March 6, which remains stationary in both eyes.

Visual fields normal. No contraction, no scotoma, no dyschromatopsia.

R. E. V = 10/10.
L. E. V = 10/10.

At this date one may regard the patient as having recovered. It remains to be seen what course will be taken by the pigmentation of part of the scleral ring.

April 4, 1916. The slight red pigmentation bordering the scleral ring persists, but shows a tendency to disappear.

Discharged April 4, 1916.

**Fracture of left orbit; right macular choroido-retinitis.**
(Case 28.)

J. B., Infantry, wounded at V., Feb. 29, 1916, by shell fragment. Dressed at once, he was sent to B. and Limoges. From his depot, July 13, 1916, on complaining of weakening of the visual acuity of the right eye, he was sent on to us.

*Condition.*—The existence of a mobile cicatrix is noted, not painful, 4 cm. long, in the form of an E, situated a little above the superior exterior angle of the left orbit. On palpation a slight depression of the subjacent bone is felt (frontal fossa and orbital process of the frontal bone).

The left eye, corresponding with the wounded side, is emmetropic; V = 10/10. The transparent media and the deep membranes are intact.

The right eye, which has not been bruised, is, on the contrary, the seat of slight mydriasis, with manifest slowness of action of the photo-motor reflexes.

The ophthalmoscope shows no lesion of the refringent media.

On a level, however, with the external margin of the disc there is a hæmorrhagic band, about 1 mm. broad, over two-thirds of the papillary circumference. This hæmorrhagic crescent in this position suggests hæmorrhage into the sheaths of the optic nerve.

In the sub-macular zone there is also a retinal hæmorrhage in the shape of a haricot bean, with the hilum upwards, corresponding on perimetric examination with a semi-annular scotoma, para-central and superior (Fig. 1, Plate I).

The visual acuity of this eye equals 1/10 barely.

B. was discharged June 5, 1916, convalescent. On his return, Aug. 5, his condition remained stationary.

**Fall on the head from shell explosion; indirect lesion of optic nerve; hæmatoma of sheath.** (Case 29.)

B. C., Infantry, wounded at Fl., Sep. 6, 1916, by the explosion of a shell which threw him to the ground; he fell on the back of his neck. A few moments afterwards, the patient tells us, there was a considerable hæmatoma of the eyelids and conjunctiva. He found that the sight of the left eye was damaged immediately after the injury. He was evacuated to Bourges a week later.

Oct. 26 he had seven days' leave. He returned to his depot, thence to Pau, afterwards to Bordeaux.

*Condition.*—Dec. 12, 1916, there was pigmentation from tattooing by powder of the sclerotic, and, at the internal border of the cornea, towards eleven o'clock, a speck which is probably consecutive to a traumatic keratitis; the anterior chamber is normal, the reflexes, although diminished, are present.

The lens and the vitreous are normal; the disc presents an unusual aspect. In the peri-papillary region there is an abnormal pigmentation of brownish colour, especially

well marked on the internal border (inverted image). (Fig. 36.)

In the inferior internal portion of the disc there is a notch; it seems as if in this position the pigmentation overlaps the border of the disc.

The rest of the papilla appears normal, the vessels

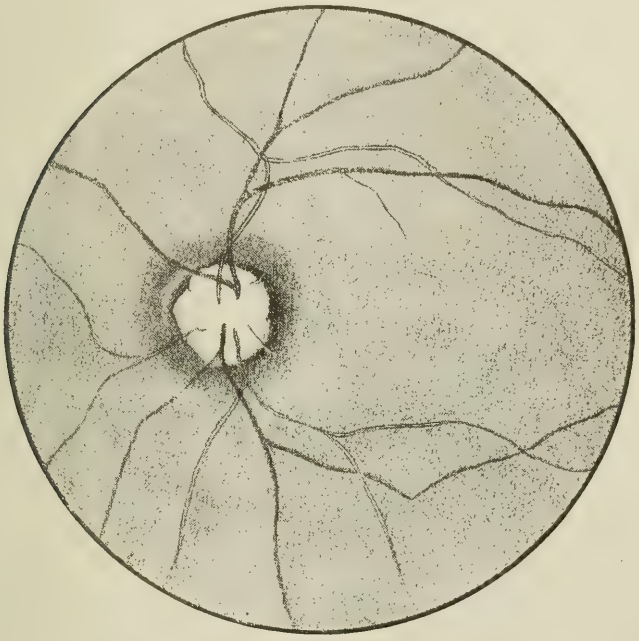


Fig. 36.—Peripapillary hæmatic pigmentation of traumatic origin.

having their physiological calibre. The macula presents a slightly congested aspect and is clearly differentiated from the rest of the fundus. It is, however, probably normal.

R. E. V = 10/10.
L. E. V = 2/10.

In this case we think that a traumatic hæmorrhage of the optic nerve has caused compression of the macular bundles, and that, little by little, the compression

has disappeared in proportion as the hæmorrhage has been absorbed.

The formation of this pigmented ring is not due to the propagation of the hæmorrhage, but to the migration of hæmatic pigment; and in the discussion which took place at the Société d'Ophtalmologie de Paris, in 1913, on the subject of DUPUY-DUTEMPS' work, KALT very rightly remarked that the production of this pigmented ring could be quite well brought into accord with the anatomical reports of DUPUY-DUTEMPS. The propagation of an effusion of blood and the migration of blood-pigment after the resorption of hæmorrhage are very different matters: the second might occur without the first.

There is a nutritive current going from the optic nerve towards the eye which is perfectly capable of carrying the pigment from behind forwards and of depositing it, on its entry into the eye, in the cribriform plate and in the choroidal zone which immediately surrounds the disc. It appears to us that this pigmented ring should always be regarded as the sign of an old hæmatoma of the optic nerve, and several times amongst our wounded cases we have been able to give it this signification (Fig. 36; Plate 1, Figs. 1 and 2).

### B.—LESIONS OF THE VESSELS. TRAUMATIC HÆMORRHAGES INTO THE ORBIT

Traumatic effusions into the orbit have been known since CARRON DU VILLARDS, who well defined consecutive exophthalmos as "a compression and a hernia of the eye." He reports the case of an unfortunate colleague who died after a fall on the pavement; at the autopsy there was found "a fracture of the orbit near the optic foramen, the ophthalmic artery and vein having been ruptured; the eye was thrust forward by an enormous clot of blood."

Accoucheurs have long noted intra-orbital effusions after the application of the forceps, and in all the classic works on ophthalmology we find very precise

indications on the subject of orbital hæmorrhage. MACKENZIE mentions a very interesting case of intra-orbital hæmorrhage, accompanied by abundant epistaxis and ending in death. DESMARRES, in his chapter on affections of the orbit, speaks of tumours produced by the extravasation of blood in the cellular tissue (*Tumeurs de l'Orbite*, Vol. I, p. 230).

DEMARQUAY describes in his *Traité des Tumeurs de l'Orbite* (*a*) effusions of blood, following fracture; (*b*) effusions of blood, following wounds; (*c*) effusions of blood, following contusion; (*d*) spontaneous effusions of blood.

On the subject of traumatic effusions of blood, the only class which interests us, he recalls the cases of the authors we have just mentioned and gives several unpublished cases of his own, notably the case of a young man of sixteen who, falling from the mast of a ship upon the deck, had such an intra-orbital hæmorrhage that the eye came out of the orbit and hung over the nose immediately after the accident. The visual function was completely lost, but the eye completely resumed its place after some months, without surgical interference.

DE WECKER devotes a chapter to hæmorrhages into the orbit, and distinguishes two classes of traumatic hæmorrhages: those which are produced by direct lesions and those which are the result of indirect. He expressly mentions projectiles amongst the causes.

The authors who have written on the subject disagree entirely as to the relative frequency of this kind of accident. According to CARRON DU VILLARDS it is very common in injuries of the orbit; according to BERLIN it is very rare. According to our cases the first author is right, since all our orbital cases, wounded by projectiles of war, presented in the early period of their injury exophthalmos more or less pronounced, which must obviously be attributed to an effusion of blood, in many cases very abundant.

The source of this intra-orbital effusion of blood

varies; it may come from the vessels of the orbit or surrounding parts, or from the intra-cranial vessels.

The hæmorrhages arise sometimes from an injury to the ophthalmic artery or vein, and it is by such injuries that one can explain the appearance of an aneurism at a later stage. As a rule the blood which is poured out behind the eye comes from a lesion in the trunk itself or from one of the important vessels at the posterior part of the orbit. Sometimes, however, the extravasation of blood begins in the cellular tissue of the eyelids and works backwards, passing from the superficial to the deep portion of the orbital cavity. Further, in the greater number of cases, the cause of the hæmorrhage cannot be exactly located. That is precisely the position in which we find ourselves with regard to our patients, for they have all recovered, and hence we have not been able to study the anatomical condition in detail.

We must compare with these traumatic intra-orbital hæmorrhages those which sometimes result from a too free tenotomy and those which happen after a Krönlein's operation, or simply after an enucleation in which the operator's scissors have strayed behind Tenon's capsule.

Sometimes the blood comes from fractured bones; the bones of the orbit are in certain places thick and richly vascularised by the vessels which run either in the diploë or in the compact tissue. When ruptured they bleed into the orbit, and must often be the cause of the hæmatomata met with in our patients. The hæmatomata of the orbit in the newly born, delivered by means of forceps, have generally a hæmorrhage of bony origin as their cause.

When the blood comes from intra-cranial vessels it may enter the orbit in several ways, according to J. Rollet, who wrote an excellent account of the subject. Sometimes it passes through a fissure in the fractured orbital vault, thus bringing the blood extravasated beneath the pia mater into communication with the orbital chamber. In this case not only the vessels

of the pia mater, but also the vessels of the brain bleed. In certain fractures of the orbit, of which we shall report cases later, the frontal lobe is reduced to a pulp; above the orbit a large aperture establishes free communication between the cranial and orbital cavities, and we find behind the eye a blackish mass continuous with the brain.

In other cases extravasation of blood takes place under the detached dura mater and extends into the coverings of the optic nerve. There are, further, cases in which a splinter of bone, detached from the orbital wall, has wounded a meningeal vessel. MACKENZIE, again, quotes a case of comminuted fracture of the orbital vault, which lacerated the cavernous sinus, and produced in consequence a very large effusion.

Again, the blood may reach the orbit through a natural aperture, the optic foramen, follow the sheath of the optic nerve and produce an intra-orbital hæmorrhage, at the same time as a hæmatoma of the nerve-sheaths, the subject with which we were dealing above.

Moreover, to J. ROLLET is due the merit of having been the first to point out orbital hæmorrhage by contre-coup.

Finally, blood may also come from the nasal cavities and sinuses. It is not rare in orbital fractures for the orbital wall to be staved in. The mucous tissues of the nose, very richly vascular, almost erectile, bleed at the same time into the nasal fossæ and into the orbit; the frontal sinus is less vascular, but when it accidentally communicates with the orbit, it may also fill it with blood. Similarly the maxillary sinus when seriously injured may become filled with blood, which overflows into the orbital cavity.

*Symptoms.*—The chief symptom is exophthalmos; the accessory symptoms are subconjunctival ecchymosis and infiltration of the eyelids.

The exophthalmos is remarkable for the rapidity of its development. It is direct—that is, the eyeball is thrust forwards almost as if it were a question of a tumour of the optic nerve; it is easily reducible, and

becomes more marked when the patient leans the head forwards. The circumstances under which it has occurred scarcely permit of any error in diagnosis.

Subconjunctival ecchymosis may occur, even when there is no exophthalmos—that is to say, when the very moderate intra-orbital hæmorrhage merely suffuses the tissues. The fluid blood slowly spreads through the orbital tissues as far as the conjunctiva, which becomes ecchymosed only after the lapse of time, twenty-four to forty-eight hours, or sometimes more. It is one of the classic signs of fracture of the cranium which has been studied by QUESNAY in the *Mémoires de l'Académie de Chirurgie* and demonstrated by VELPEAU. Its delayed appearance in fractures of the orbit from projectiles of war indicates a fracture of the base of the skull.

It is well, moreover, to distinguish clearly between the outpouring of blood which results from a fracture of the orbit and that which follows a direct contusion of the soft parts. We are again indebted to J. ROLLET for a valuable article in which he has established, (1) that ecchymosis due to a fracture spreads by degrees; (2) that it is limited to the conjunctiva and its palpebral folds; (3) that it produces only a moderate amount of tumefaction: whereas that which follows on contusion is very rapid in its onset, spreads to the soft parts of the face, and readily assumes large proportions.

Hence, when we find (as in Cases 17, 20, 21, etc.) well-marked exophthalmos and profuse ecchymosis we must regard them as due to lesions of the soft parts with laceration of the orbital vessels.

When there is no infection of the wound hæmorrhage is often absorbed quickly, the exophthalmos disappears, and the visual functions are restored in proportion as the optic nerve and the sensori-motor apparatus have remained intact. But it may happen that the orbital wound becomes infected; orbital cellulitis then ensues, by no means a negligible complication. It must be pointed out, however that this infection is quite rare. Perhaps the patients attacked with it do

not get as far as our hospital and have been treated at the front. It is remarkable, however, to note amongst the hundreds of fractures of the orbit which we have examined the smallness of the number of those complicated by infective cellulitis of the orbit. We have only seen two cases, which may be summed up thus:

In the first patient a bullet penetrated at the level of the left zygomatic arch and emerged by the left orbit, rupturing the eyeball, which was enucleated the day following the injury. When he came under our care, six days later, he presented all the signs of orbital cellulitis (extreme œdema of the lids, voluminous chemosis, conjunctival suppuration); further, the signs of meningeal reaction were present (KERNIG'S sign, slow pulse, temperature 38·6° C. (101·2° Fahr.) vomiting). A lumbar puncture proved negative; incision and drainage of the orbital cavity, with the application of ice to the head, brought the infection under control, and recovery rapidly followed.

The second patient was struck by a shell fragment which penetrated at the level of the root of the nose on the right side, traversed the right lacrymal sac, the nasal fossæ, the left orbit, and finally lodged in the left temporal region. The eye was in a condition of exophthalmos, and ophthalmoscopic examination showed detachment of the papillo-macular region of the retina. Three weeks after admission orbital cellulitis appeared; an incision through the external wall permitted the escape of a large quantity of fœtid pus; there was osteo-periostitis of the orbital wall. Recovery was very slow, and on Dec 31 the patient showed signs of suppurating ethmoiditis, which necessitated his removal to the rhinological department. Jan. 13, he was returned to us as an urgent case, the orbital infection having returned; we then noted the evidences of meningeal reaction (KERNIG'S sign, vomiting, temperature 38·4° C. (Fahr. 100·6°).

The general symptoms rapidly grew worse, and we made a lumbar puncture which yielded almost pure pus. Jan. 22, the patient died, probably from a

cerebral abscess previously latent, opening secondarily into the meninges, consequent upon infection of the encephalon through the orbital aperture.

Orbital cellulitis is therefore an exceptional complication. We explain its rarity by suggesting that usually the bullet or fragment of shell which enters the orbit does not carry with it shreds of dirty clothing, and that the orifice of entry, usually very small, closes spontaneously sufficiently quickly to escape the dangers which may attack a wounded man who does not obtain immediate attention.

When the instrument of trauma is not infected or such as is capable of infecting the orbital cavity, it may happen sometimes that infection proceeds from the fractured nasal fossæ, which freely communicate with the focus of hæmorrhage. We have recently seen an example, which, although it is not a war case, merits none the less to be reported here.

A boy aged eleven, when running, fell suddenly on his nose; there was immediate epistaxis and very marked exophthalmos, indicating intra-orbital hæmorrhage from rupture of some important vessels; six days later inflammatory complications appeared (fever, great pain, well-marked and painful swelling at the angle of the eye, above the lacrymal sac). It soon became evident that a large purulent collection had formed behind the eye; it was necessary to incise and drain. This procedure resulted in rapid and uninterrupted recovery. It is quite probable that infection of the orbital pocket of blood resulted from the fracture of the os planum and laceration of the mucous membrane of the nasal fossæ. Thus the infection-carrying substances from the nose penetrated into the orbit.

It would be natural to expect that in fractures of the orbit by projectiles of war, in which the nasal fossæ and the nose are largely involved and put in communication with the orbital chamber, such an infection would be frequently produced. We are bound to admit that it is not so, and that in practice this complication is very rare.

What we have observed concerning intra-orbital hæmorrhages amongst our cases nearly always consists in a rapidly formed and well-marked exophthalmos, which yields little by little to the influence of time without resulting in permanent damage.

When fracture implicating the orbital vault allows of free communication between the orbital chamber and the brain events happen due to the cerebral lesion itself; some interesting cases of this will be given later.

### C.—Traumatic Lesions of the Extrinsic and Intrinsic Muscles

A certain number of cases are reported of paralyses of muscles of the eye due to contusions and to orbital injuries. All instruments of violence, whether cold steel or projectiles, may implicate more or less gravely the recti and oblique muscles of the eye; the muscle is thrust against the orbital wall and crushed. Bernheim quotes the case of a child who, flinging himself against a door, ruptured the internal rectus near its bulbar insertion.

Panas, in 1902, collected the published cases of traumatism of the ocular muscles, and remarked that the chief agents were contusions, accidents with foils, horns of cattle, blows against hard substances, doors, sticks, etc.

The pathological anatomy of these muscular ruptures is not exactly known, for usually the surgeon intervenes too late, when the repair is already effected. In two cases only, one by Panas and one by Graefe, the muscle was torn at its insertion into the sclerotic. It is probable that in other cases the rupture occurred in the muscle itself. There is good reason for this view in that traumatic muscular paralysis is usually direct—that is, the muscle itself is contused or crushed, hence it is there that the solution of continuity should occur. Besides, ruptures of muscles are produced, as is demonstrated by the general surgeons, sometimes in the fleshy portion, sometimes in the tendon, according

as the muscle is injured at the moment of contraction or at the moment of relaxation. MALGAIGNE, taking the idea from DELPECH, carried out some noteworthy experiments in connection with this subject. "Muscular rupture," he says, "only takes place when the muscle is stretched and elongated, rupture of tendon when the muscle is shortened and contracted." So far as concerns the muscles of the eye there is no reason for refusing to accept this opinion of the general surgeons.

Since the work of PANAS, GARIPUY and DEMICHERI have published cases of paralysis of the superior oblique, and TERRIEN has reported a case of partial paralysis due to an effusion of blood which filled the cavity of the left maxillary sinus.

TERSON and COSMETATOS have published similar cases.

Sometimes the injury causes an effusion of blood into the sheath of the muscle; paralyses by intramuscular hæmorrhage (DE LAPERSONNE) are produced in this manner. We do not dwell upon this subject because we do not wish to pass in review all the published cases; it will suffice if we place on record here those which we have observed, and which are as follow:—

We have noted seventeen cases of this kind. The seat of the orbital fracture is in immediate proximity to the muscle attacked; we draw particular attention to fractures of the roof, which were accompanied nine times by paralysis, either of the levator palpebræ, or the rectus superior, or both together. In four of our cases paralysis of the inferior rectus alone coexisted with a depression of the median portion of the inferior orbital margin. Another patient, after an infero-internal wound of the orbit, was affected with diplopia due to paralysis of the inferior oblique. In another case the external rectus was traversed by a revolver bullet. Finally, we cite two cases of detachment of the pulley of the superior oblique following a smash of the corresponding frontal sinus.

In four other cases it is more plausible to admit the hypothesis of a fracture radiating to the apex of the orbit. These, after a depressed fracture of the frontal bone or of the supero-external angle of the orbit, had several extrinsic muscles paralysed at the same time. We may suppose that a lesion of the nerve filaments themselves at their entry into the orbit had occurred, for this best explains the multiplicity of symptoms. These four cases may be summed up in this manner—

(*a*) Paralysis of the superior rectus and the levator palpebræ, with internal ophthalmoplegia.

(*b*) Paralysis of the superior rectus, the levator palpebræ, and the internal rectus, with internal ophthalmoplegia.

(*c*) Paralysis of the superior rectus, the internal rectus, and the inferior oblique.

(*d*) Paralysis of the superior rectus, the inferior rectus, and the superior oblique.

Finally should be mentioned two cases of paralysis, one of the superior rectus, the other of the superior oblique, consecutive, one to a bullet going to the apex of the orbit, the second to a fracture of the fronto-temporal region after a fall on the head, in which the nerve-trunk alone seems to have been involved.

*Intrinsic muscles.*—In reviewing the action of gross injuries of the orbit upon the intrinsic muscles of the eye no one will be surprised if we give a considerable number of examples. We have very frequently observed paralysis of the sphincter and the mydriasis which results from it, a very real mydriasis, attributable to rupture of the muscular fibres, and only very rarely accompanied by paralysis of the accommodation.

The mechanism of traumatic mydriases, by direct shock upon the eye, is well known, and when the projectile has touched the eyeball tangentially it is not surprising that such a phenomenon should occur. But when the projectile has not touched the eye the case is more interesting and merits attention.

We have met with two cases of this kind amongst the wounded who had fracture of the superior orbital

margin; they presented no lesion of the ocular membranes, and visual acuity was preserved; hence we had to ascribe this paralysis of the pupillary and ciliary muscles to concussion.

We now come to the affections which implicate the eye itself. We shall consider successively those which occur—

(1) In the transparent media.

(2) In the deep membranes, where we shall make two subdivisions, (*a*) lesions of the uveal tract, (*b*) lesions of the retina.

## D.—Lesions of the Eyeball

### (1) Affections of the Transparent Media

*Cataracts from Contusion and Concussion of the Lens*

Opacification of the crystalline lens, consecutive to contusion of the lens without rupture of the capsule, is incontestable. It is not even rare, so that Arlt, Liebreich, Desmarres and Warlomont were wrong in doubting it. De Wecker, Berlin, Becker and Fuchs have demonstrated its existence both clinically and by experiment. The last author has written a remarkable essay upon the subject; he describes three types of anterior polar lesions.

(1) Starred form, with rays in arranged sectors, increasing in thickness towards the periphery.

(2) Rays terminating in a point towards the periphery.

(3) Arrangement in the form of leaflets.

These are superficial epithelial troubles, capable of disappearing. Lesions of the posterior pole are more serious and are dissipated with difficulty; is it possible that there is in this case a delicate invisible laceration of the capsule in the hyaloid fossa?

It is certainly not impossible, and it is the opinion to which Bonnefon, who has made an interesting study of the question, is inclined.

This author thinks that in the affections of the anterior pole of which FUCHS speaks it is a question of epithelial disorders not affecting the lens fibres. The normal unions of the various parts of the lens become separated, but there is no cataract properly so called; if the striæ persist, they are situated at the site of dislocation of the fibres, and he believes that when a rapidly developing cataract is produced after a contusion there exists a rupture of the capsule.

We have observed, clinically, cases which agree well with BONNEFON'S opinion; we have a very clear recollection of a patient who, after a contusion of the eyeball, presented at the posterior pole a star-shaped cataract which seemed likely to progress rapidly. This was an error in prognosis, for the polar and stellar opacity became absorbed. It is quite possible, in fact, as BONNEFON thinks, that posterior polar cataract may become absorbed when there is no rupture of the capsule, and on the contrary, will become complete when a rupture exists, however small this may be. We need not allow ourselves to be disturbed by the objections of those who quote as argument for cataract without rupture what happens in experimental (naphthalin) cataract. There it is a question of disturbance of the lens analogous to that in spontaneous cataract, which depends evidently upon an alteration of nutrition, more or less unknown, and which has nothing in common with traumatic cataract.

But still more interesting are the cases consecutive to air concussion—what the old writers called "the wind of the cannon-ball."

We have seen several typical cases, notably two instances reported by our assistant, DR. HARRIET, which deserve to be placed on record, because they are two very clear examples of lens opacity, of true cataracts, due to the shock of aerial waves on the eyeball: two men, walking side by side upon the same level were violently thrown to the ground by the bursting of a shell. In addition to superficial injuries and slight contusions, both immediately complained of a

sensation of burning in the eye and of a slight diminution of sight.

Nine days after the traumatism these cases presented, besides traumatic mydriasis, a star-shaped posterior polar cataract; the branches, to the number of six, very irregular in one case, a little more marked in the inferior portion in the other, occupied the posterior pole of the lens. Three months later the cataracts, evolving normally, were almost complete.

The offending agent here was the concussion of the aerial waves produced by the explosion of the shell, and it is probable that the posterior capsule was the seat of a small laceration.

We do not dwell upon these two cases, which do not strictly belong to fractures of the orbit; we have drawn attention to them on account of the analogy which they present to cataracts produced by the concussion imposed by projectiles upon neighbouring parts of the eye.

We are able to report three examples of these cataracts by concussion, due to traumatism in the neighbourhood of the eye.

One case had a fracture of the right temporal bone, with cerebral pulsation perceptible; the right eye had an intumescent cataract, and the excellent light reflexes allowed us to conjecture that the deep membranes were intact.

The second case also had an intumescent cataract of the right eye, with preservation of the globe, without injury to the media, an affection consecutive to a fracture of the superior margin of the orbit by a fragment of shell.

In the third case, with a fracture of the supero-external angle of the orbit, there was iridodialysis on the side of the bony depression and total cataract. Examination of the reflexes, however, indicated that there was serious damage to the choroid and retina (hæmorrhage or detachment).

It follows from what has just been said, and particularly from our cases, that we cannot accept the

conclusion of EGNER, admitted by DOR (*Encyclopédie française d'Ophtalmologie*, Vol. VII, p. 13): "Cataracts by simple contusion can no longer be considered as a rarity, whilst cases of rupture of the capsule by simple contusion are rare."

What do these authors know about it, and upon what are they basing their assertion concerning the rarity of capsular laceration?

In the cases of concussion by displacement, such as those which we report, where it seems at first sight that the capsule should have been spared, nothing is less certain, since we know that the shock of an aerial wave is capable of dislocating a lens or rupturing the uveal tract—why should it not be able to rupture the lens capsule?

We are of opinion, with BONNEFON, that the anterior epithelial mischief and the disturbances of the various segments dislocated backwards are susceptible of absorption when the capsule is not ruptured: there is no true cataract in such cases. When the cataract progresses and becomes complete, it is probable that the capsule is torn somewhere near the part which earliest becomes opaque.

### *Subluxation and Luxation of the Lens*

We have observed several cases presenting no essential differences from lesions of the same order which are common enough in civil practice, notably in occupational accidents. We will quote only one case, concerning a luxation of the lens upwards, which remained for some months suspended by a narrow band of the suspensory ligament without falling into the vitreous. In saying that such lenses are not the seat of cataract we are saying nothing out of the common, because, in this case, the force which loosened the lens met with no resistance, and the lens escaped without contusion.

A more interesting fact from the point of view of military ophthalmic surgery is the tolerance of the

eye towards a dislocated lens; even in cases when the luxation has been complete we have generally found that it leads to no further damage. This was so in the two cases of subluxation we saw amongst cases of fracture of the orbit.

The first case was one of fracture of the left frontal bone and the vault of the orbit, with manifestation of cerebral pulsation; in the left eye we noted, besides optic atrophy and pigmented choroido-retinitis of the macular region, subluxation of the lens, which was still transparent, down and out. In the second case the left upper eyelid had been partially destroyed by a piece of shell; there was a breach in the superior orbital margin; the left eye presented complete optic atrophy, iridodialysis up and out, and subluxation of the lens down and out.

(2) Affections of the Membranes: (*a*) Uveal Tract

In the study of the complications which involve the sclerotic we have no case to report, because, when the projectile has fractured the orbit and directly injured the eye, the globe has burst, not at any peripheral spot, but over a very large extent; it has been destroyed.

Limited scleral ruptures do not apparently occur in military surgery. Out of 609 cases of fracture of the orbit, in 212 the globe has been destroyed by bursting; in 105 the globe has been spared completely; in 292 the deep membranes have been damaged; not once has the sclerotic been ruptured in a limited region.

The fact is indeed surprising, but one can only bow to the clinical evidence, and in our work there is no occasion to speak of partial ruptures of the eyeball.

We pass on, therefore, to traumatic lesions of the uveal tract.

In the serious contusions suffered by the eye in fractures of the orbit, we shall consider in the first place lacerations of the pupillary margin of the iris, and detachment of the ciliary border; in the second place ruptures of the choroid and detachment of this

membrane. We shall pass in review successively the distinctive features which these affections have presented amongst our wounded.

### *Lesions of the Iris*

*Laceration of the pupillary border.*—It is known that lacerations more or less visible, though rarely visible even to oblique illumination, are the common cause of traumatic mydriasis after contusions of the eye. It has happened to us to be able to identify linear gashes in the form of triangular fissures. One of our patients, observed recently, had this condition in conjunction with a very marked mydriasis, showing two small radial fissures between six and seven o'clock; these tears must be looked for with the corneal loupe. They are visible under the great magnification given by this instrument when the most careful examination with an ordinary lens fails to detect them.

We are concerned, as we said above, with a traumatic paralysis directly affecting the muscle, and one in which there is no lesion of the nervous system. It is probable that these lesions of the sphincter happen when the contusion of the iris takes place through a cornea struck perpendicularly to its basal plane; the muscular fibres of the iris are themselves compressed, crushed between the cornea and the lens, which resists only so far as it is supported by the hyaloid fossa. In our cases it has been impossible to discover the direction in which the force acted most strongly.

*Dialysis of the iris.*—There are several theories to explain iridodialysis.

According to SCHMIDT-RIMPLER, traumatic iridodialysis is due to depression of the sclerotic by the object which strikes the blow. The insertion of the iris suffers an amount of traction which is all the greater because the injury produces at the same time contraction of the pupil, as was shown by BERLIN. The iris becomes torn away close to its attachment.

FÖRSTER, relying upon experimental researches,

points out that the aqueous humour is driven back towards the centre of the eye. The iris is closely applied to the lens, thus closing the communication between the anterior chamber and the posterior chamber; the pressure stretches the iris from before backwards and ends by causing it to give way in the part where it is not supported by the lens, *i. e.*, towards the periphery.

Sattler admits the simultaneous action of the depression of the sclerotic and the forcing back of the aqueous humour.

Ballaban, however, points out that, the globe being full of fluid, there can be no marked difference of pressure between the aqueous humour and the vitreous. The iris cannot therefore be driven back against the lens. According to this writer the sclerotic is depressed at the same time as the pupil contracts; the wall of the globe, which is very elastic, then recoils upon itself, overpassing the limits of its initial position. The iris cannot follow it and is torn at its base, which is the least resistant portion and the point of maximum traction.

It is essential, therefore, that the blow which strikes the eye should be sudden, indeed instantaneous, and that it should attack the sclero-corneal margin. The youth of the patients is a favourable condition, because the sclerotic is still very elastic in young subjects.

The most probable of these theories appears to us to be that which explains the detachment of the iris by compression of the aqueous humour, driven back into the angle of filtration. It is possible that this may be the mechanism by which separation of the uveal tract from the sclerotic is produced; but it is difficult to suppose that the pathogenic mechanism should always be essentially the same.

We have not observed iridodialysis as a complication of fractures of the orbit, but we think we ought to report here a case of this lesion in a subject who had a double dialysis of the iris after having been

violently thrown down by a shell-explosion and struck on both eyes by fragments which injured the centres of both corneæ (Fig. 37). It seems, in fact, in this case, that the anterior chamber had been flattened out by the shock, and that the cornea had been made to touch the lens, driving the aqueous humour into the spaces of FONTANA. The space of the iridic angle had been over-distended, and the iris became detached from its base by the excess of aqueous humour which accumulated in the angle. The detachment of the iris took place all the more readily because the iris is not supported by the lens at the site of its attachment to the ciliary body. In short, FÖRSTER'S theory seems to us to give the best explanation of the case represented by Fig. 37.

Injuries of the iris, laceration of the sphincter or dialysis, may be accompanied by hæmorrhages and inflammatory complications. Hæmorrhage explains itself in dialysis, because the vascular plexus at the base of the iris may be ruptured and bleed profusely. We have not seen these hæmorrhages in our cases, because the patients have usually arrived at the base several weeks after the infliction of their injuries, so that the effusion of blood has had time to become absorbed. Lacerations in the region of the sphincter do not bleed; there is only extravasation of a few red corpuscles in the muscular tissue of the sphincter iridis.

We have not gone into the inflammatory complications further; doubtless, after such traumatism, the blood, which is laden with all sorts of toxins, may deposit them in the lacerated tissues, and thus produce inflammation of endogenous origin; so that this inflammation may result from chemically irritating toxins or from microbes directly deposited in the wound by the circulation.

Contrary to certain ophthalmologists, we firmly believe in infections of internal origin, but we have not met with them in our patients.

We explain this fact by the age of the soldiers, who

are as a rule healthy subjects. It is worn-out subjects who are liable to inflammations of internal origin, especially old people with anterio-sclerosis. The old folk we operate on for cataract, cardiacs, with hyper-tension, will get iritis in spite of perfect asepsis, even with an operation with the conjunctival flap, because they resist so badly the poisons with which their aged organisms are laden. Soldiers, habitually very strong, have supple vessels and tissues which

Fig. 37.

protect themselves well; hence injury of the iris is not complicated by inflammatory manifestations.

After traumatic lacerations of the sphincter and dialysis of the iris we must here notice cases of inversion of the iris.

This accident happens when, as a result of injury, the intra-ocular pressure in the anterior chamber is very suddenly raised: the sphincter of the iris is then thrust back into the triangular space which separates the membrane of the iris from the lens; the pupillary margin turns backwards on itself, and the whole breadth of the membrane of the iris follows the inversion of its margin; the result is that the entire

iris becomes finally flattened against the ciliary body; a true luxation of the pupil is thus produced.

We have not seen any cases of this nature.

### *Lesions of the Choroid*

Choroidal lesions present for examination: (1) Ruptures of the choroid; (2) Hæmorrhages and detachment of the membrane.

These various disorders are met with either when the eye has been struck directly, or when a concussion in the vicinity has shaken the organ with sufficient violence to rupture one of its membranes.

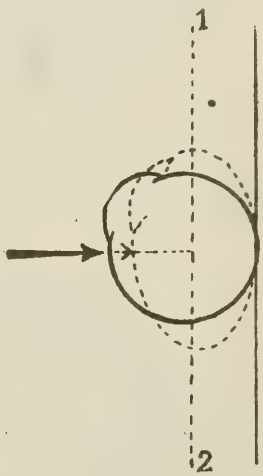



FIG. 38.—Equator of depression (Arlt).

(1) CHOROIDAL RUPTURES—These may be produced directly by traumatism implicating the eyeball itself, or may be the result of indirect lesions by concussion.

We shall now study the first variety.

(*A*) *Direct choroidal ruptures from a blow upon the eye.*—There are many theories to explain these.

(1) The theory of direct pressure (AMMON), applicable to lacerations of the anterior region of the choroid, and, exceptionally, to some lacerations at the posterior pole.

(2) The theory of contre-coup (KNAPP, BERLIN, SEIDLITZ), in which the mechanism of certain fractures of the skull is invoked.

(3) BECKER is of opinion that ruptures of the choroid at the posterior pole are due to the concentric pressure or traction of the optic nerve, exerted at the moment of traumatism upon the posterior pole of the globe.

(4) FAGE believes that at the moment of a contusion the eyeball finds itself between two resistances, the orbital wall on one side and the insertion of the

optic nerve on the other; between these two, the choroid, stretched, and only slightly extensible by reason of the vessels which bind it to the sclerotic, is torn in a direction perpendicular to that of the traction.

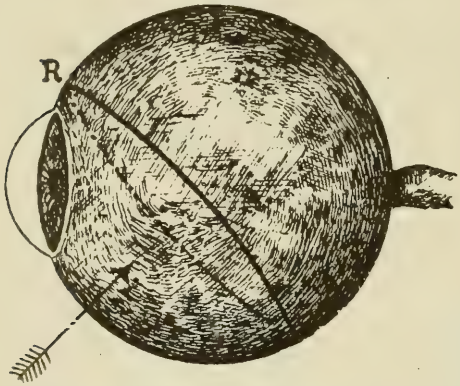



FIG. 39.—Traumatism affecting the lower part of the globe. Rupture at R, in the thinned intercalary space.

(5) SAEMISCH thinks that the choroid tears at the point where it is most firmly fixed, either behind in the region of the disc, or in front near the ora serrata.

(6) DE WECKER ascribes great importance to the sudden contraction of the muscles of the eye at the moment of injury; he thinks that this contraction deforms the globe and contributes to the choroidal rupture.

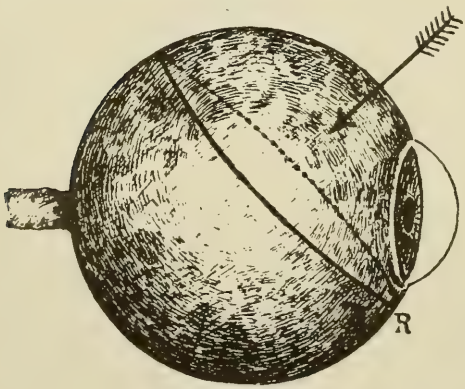



FIG. 40.—Traumatism affecting the upper part of the globe. Rupture at R, at the site of the intercalary space, the thinnest portion of the ocular wall.

ARLT defends the theory which he has brought forward to explain ruptures of the sclerotic. When a force is applied to the globe, an equator of depression perpendicular to the direction of this force is established (Fig. 38), and it is upon this equator that the rupture occurs.

We have amplified this theory of ARLT in an essay

on ruptures of the sclerotic (*Bulletin médical*, 1905, p. 201), by demonstrating that scleral ruptures are always produced at the thinnest portion of the wall of the eye—*i. e.*, between the insertion of the recti muscles and the cornea, because in the usual ocular injuries, whether the eye is struck from below (Fig. 39) or from above (Fig. 40), the equator of depression always passes through this thinned portion.

These theories retain their full value so far as ruptures of the choroid by direct shock are concerned; the uveal membrane is submitted to the same conditions as the fibrous coat and should therefore

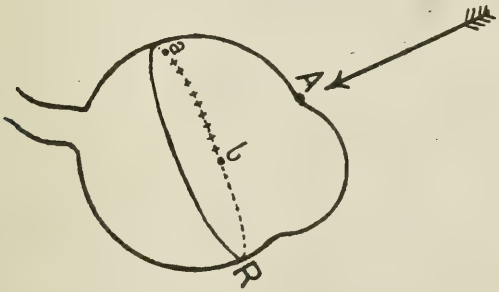



Fig. 41.

rupture on a line passing through the equator of depression.

We have had occasion to demonstrate the truth of this explanation in a case in which a young woman, looking at a display of fireworks, received the falling stick of a rocket in the eye, exactly in the position shown by Fig. 41; it was falling from a great height and consequently with much force.

The lesion produced in the eye is represented in Fig. 42, and in this case the explanation of the choroidal rupture appears to us to be as follows :—

The rocket-stick, falling with violence upon the wounded eye, struck it with great force in the direction of the arrow, at the point A (Fig. 41); there resulted an equator of depression, at the site of

which the sclerotic and the choroid were strongly stretched, and the rupture occurred from *a* to *b*; this line of rupture corresponds closely to the region lacerated in Fig. 42. The choroidal rupture takes place there all the more readily because, at this point, the choroid is not adherent; farther back, towards the disc, it adheres to the sclerotic; farther forwards it is attached to the fibrous coat of the eye by the vasa vorticosa. On the other hand, in the lacerated region, from *a* to *b*, it glides easily over the scleral wall and tears when the stretching becomes too great.

FIG. 42.—Choroidal rupture following the line of the equator of depression.

If the sclerotic of this patient had ruptured it would have yielded at R, because there the equator of depression meets the zone of least resistance of the sclerotic, as I laid down in a paper published in the *Bulletin médical* (1903). Rupture of the sclerotic, between the cornea and the insertion of the muscles, is explained by the fact that here the equator of depression meets the thinnest part of the wall of the eye.

In the same manner, when the sclerotic resists and the choroid is torn, the latter gives way at the posterior part of the equator of depression, at *a*, *b*, for example, because it is there that it is the least firmly fixed and least attached to the scleral envelope.

It is therefore the theory of the equator of depression which should be applied when the eye suffers contusion. Far from us be the thought that this

theory will explain every case, for we believe that there is great diversity in the pathogenesis of ruptures of the choroid; furthermore, there are few cases in which one is able to identify the exact seat of the initial traumatism and the direction of the force which has wounded the eye.

Perhaps it is by this mechanism that a certain number of the choroidal ruptures we have examined have been produced. The shock of the projectile upon the eye has been applied to a point of the sclerotic far removed from the choroidal rupture, which has occurred on the line of the equator of depression. But most frequently the shock has produced mischief at the actual spot where the globe has been struck; so that choroidal lesions by direct shock are usually at the contused point, much more rarely at a point removed from this spot.

It will be convenient here to make a distinction between the injuries of the eyeball caused by a blunt instrument, such as the clenched fist, stone thrown with force, etc. (the kind of contusion one meets with often enough in civil life), and the wounds which implicate the eye in war.

A blow from the fist involves the formation of the equator of depression of ARLT, and the choroidal laceration occurs far from the point struck. A projectile of war, a piece of shell, which strikes the eye directly, like a whip, does not produce an equator of depression; it destroys the organ, tearing it to pieces.

In military surgery the eye is only injured, without being destroyed, by a bullet which grazes it tangentially, or by a small fragment of shell which, with momentum diminished by its flight, strikes a circumscribed spot. There is then no equator of depression, but a wound at the place contused.

In short, what happens to the sclerotic happens to the choroid, in our cases. There are not, or at any rate very rarely, ruptures influenced by the equator of depression, because all projectiles, striking the eye

violently, perpendicular to it, lead to its destruction, pure and simple.

We have recalled ARLT'S theory and demonstrated its value, but in reality it applies very little to military surgery. In thirty months' observation in a military hospital, well supplied with patients, we have not seen a single case of scleral rupture bearing on this theory. We are less emphatic concerning choroidal ruptures; there may perhaps be a few examples, as in Fig. 44, which represents a longitudinal rupture, in a patient who had been struck by a piece of shell, exactly on the level of the left frontal sinus, the crushed inferior wall of which must have bruised the eyeball directly. It is possible that an equator was produced there, according to ARLT'S theory, and that the line of retino-choroidal rupture formed part of it. The cases in Plate IV, Figs. 1, 3 and 4, and Plate VI, Figs. 1 and 2, call forth the same reflections, but we believe that ruptures of the deep membranes rarely depend on this mechanism; the lesions of the uveal tract which result from a blow on the eye are situated at the point struck.

The lesion thus produced is, moreover, serious. There is free hæmorrhage, invading the vitreous—these are the cases which result in retinitis proliferans. We have noted a considerable number of cases of this condition, which would risk encumbering this work needlessly if reported here.

(*B*) *Indirect or mediate choroidal ruptures.*—The cases which I have now to bring forward are *intra-ocular disorders consecutive to concussion in the vicinity of the eye.*

These cases are rare, and have been but little studied. But they are not the only ones which have been reported in our scientific records, and, without pretending to give here a complete bibliography, we can quote a case from VON AMMON, which appears to be the first, of rupture of the choroid by concussion; CARL GENTH, at PAGENSTECHER'S Ophthalmological Institute, observed three cases in which lesions of the

ocular membranes occurred, without the eye having been touched, following injuries to the bones of the orbit.

Joy Jeffries, of Boston, reports a case of rupture of the choroid without direct lesion of the eye, which resembles in every respect the cases which the reader will find below.

A young man, aged fifteen, was about to enter a barn; he struck his forehead against a beam, and the shock stunned him. He was not, it seemed, very seriously injured, the effect of the blow having immediately passed off; but three days later he saw black patches before the left eye. On examination, two crescent-shaped lacerations of the choroid were found.

Two similar cases are reported in much detail by Mannhardt.

The first concerns a man of thirty-five who was carrying, with a comrade, a heavy load, which the latter dropped suddenly. A laceration of the choroid was produced, which the author does not hesitate to attribute to concussion.

In the second case the rupture of the choroid was due to a fall from a height of forty feet.

Parisotti and Haas have published similar cases. The latter author's case was a child of nine years, struck on the head in the neighbourhood of the right eye by a violent blow with a stick. He showed, after absorption, hæmorrhages into the vitreous, and crescent-shaped laceration of the choroid and retina immediately above the disc.

Choroidal injuries by vibratory shock are therefore well known; and Norman Hansen is certainly in error when he denies their possibility, as he does in a work entitled, "Under what conditions can a choroidal laceration be produced in gunshot wounds of the temporal region?" This author believes, from the study of eight cases, that choroidal rupture takes place only when the projectile strikes the eyeball directly, or when distension of the globe is produced, as in the case of violent laceration of the optic nerve.

Norman Hansen is right so far as injuries of the optic nerve are concerned. It is certain that a bullet, striking the nerve behind the eye, stretches the ocular membranes in a direct manner; and when the projectile has traversed the orbit behind the eyeball the traumatism is in some way directly transmitted to the intra-orbital membranes by the stretched optic nerve. We report several very clear cases, but Norman Hansen is in error when he denies the possibility of choroidal ruptures from lesions in the neighbourhood, where none of the organs contained in the orbit has been directly implicated.

De Wecker was better inspired when he wrote: "All those who, during the sad war of 1870, had occasion to examine many injuries to the head, submitting the wounded to ophthalmoscopic examinations, have been able to convince themselves that ruptures of the choroid constantly accompany, in some way or other, all the concussions and violent shocks to the bony framework of the upper portion of the face."

The possibility of the lesions which we are about to study, therefore, is generally accepted by ophthalmic surgeons, but we do not think that, up to now, these affections have been reported with any details, and it is for this reason that we wish to publish the cases which follow. They have already been the subject of a paper communicated to l'Académie de Médicine, May 15, 1915. Before this date Yarr, Lègues, Charles Lee, Harman, quoted by Prof. Baudry (*Traumatisms de l'œil au point de vue médico-légal*, p. 168), had reported cases of loss of vision following shell-explosion by indirect concussion, but, no more than the authors cited above, had they described the lesions in the fundus of the eye. Our publication of May 15, 1915 is the first in which the macular lesions and the choroidal lacerations have been studied and represented in detail. A little later, our colleague Terrien, in the *Archives d'Ophtalmologie* appearing at the end of June, 1915, quoted cases which may in every respect be placed beside ours, and which entirely

corroborate our conclusions relative to macular lesions by concussion. We would reproduce them here, were it not that the limits of this book, in which we are not publishing the fourth part of our own observations, forbade it. We may say the same of DANTRELLE's cases (*Archives d'Ophtalmologie*, Sep.–Oct. 1915), who has published representations of the fundus of the eye, analogous to ours, some months after us, and who, perhaps, has not adequately noted that our article contained cases, similar to his, of macular lesions by concussion, following violent injury to the bones of the face.

Similar cases, moreover, are being quite generally observed; at the "Centre secondaire d'Angers" GINESTOUS has been able to collect a large number (*Gazette hebdomadaire de Bordeaux*, Nov. 1916).

All the personal observations which are now about to be placed before the reader would have found a natural place in groups II, III, and IV (p 813 *et seq.*) of cases reported to demonstrate the truth of the laws which govern lesions of the eye in injuries implicating the orbital region. We thought it better to record them here, because we shall be able to describe in detail the lesions of the choroid and retina with their manifold ophthalmoscopic varieties.

The cases reported above (p. 814 *et seq.*), in five groups, are merely examples; we have only grouped a few in each category; we might have doubled or tripled the number, for on this subject we have abundance of evidence.

The same applies to the cases which follow; they are chosen from amongst many others, similar, and of equal clinical value.

**Wound of right temporal fossa; detachment of retina, R. E.**
(Case 30.)

C., wounded Oct. 29 by a rifle bullet which penetrated above the right eyebrow (at the level of the external third), traced a deep furrow in the temporal muscle and emerged a finger's breadth above the right tragus.

The external orbital margin is fractured, as well as the malar process of the maxilla; the latter fracture causes deformity of the floor of the orbit and the globe is slightly deviated downwards. Beyond this the eye presents no trace of injury.

Examination shows that the right eye has only quantitative vision. There is a large detachment of the retina.

The left eye, normal, has acuity 1 with + 0·75 D sph.

**Perforating wound of the right temporal fossa; rupture of choroid, R. E.** (Case 31.)

L., wounded at Ypres, Nov. 5. A bullet penetrated near the outer end of the right eyebrow, close to the orbital

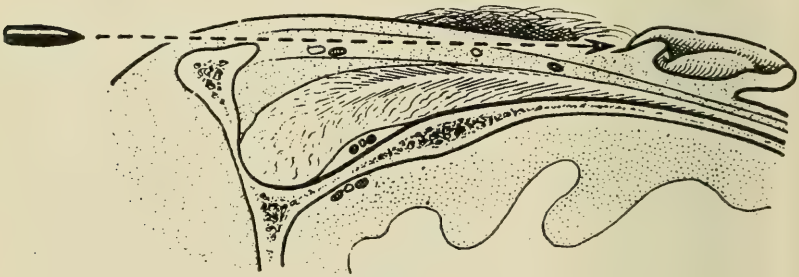


Fig. 43.

margin, which, however, it did not injure; it emerged from the temporal fossa after a perfectly horizontal course two fingers in breadth in the cellular tissue; radiography showed no bony lesion.

The right eye presents outwardly no trace of injury, but has only quantitative vision. Study of the visual field shows that central vision is abolished, and the ophthalmoscopic examination reveals grave lesions. The whole of the posterior pole is covered with abundant pigmentation, through which it is possible to see, near the macula, a severe laceration of the choroid in the form of a crescent, the convexity of which is turned towards the disc. The left eye is normal (Plate V, Fig. 1).

**Contusions of the left orbital margin; rupture of choroid, L. E.** (Case 32.)

P., wounded Oct. 6, near Arras. He was struck by a

la ge piece of shell, which injured at the same time the infra-orbital region and the bridge of the nose, producing in this region contused wounds, but leaving quite intact the eyelids and the globe itself.

R. E. has an acuity of 9/10 with correction; the visual field is normal; no lesion can be found.

L. E., acuity = 1/100, not improved by glasses; with the ophthalmoscope numerous floating bodies in the vitreous and serious lesions of the membranes are seen. A large laceration of the choroid, of irregular form, occupies the posterior pole quite close to the macular region.

It is surrounded by an inflammatory zone, characterised by dense black pigmentation.

A large detachment of the retina is situated below. This latter lesion disappeared after some weeks of treatment, but vision was not improved.

The lesions of this eye are manifestly and essentially choroidal lesions. Over the portion of the rupture nearest to the disc five retinal vessels may be seen passing over the tear in the choroid; in the same way, two vessels are very evident crossing the choroidal rupture perpendicularly in a part furthest from the papilla. Another vessel seems to have disappeared, but in reailty it has been covered by proliferating retinitis (Plate V, Fig. 2).

**Traumatism of the malar region; optic neuritis; rupture of the choroid, R. E.** (Case 33.)

R. was struck by a bullet, Sep. 6. The projectile penetrated one centimetre behind the right angle of the mandible, and emerged by a large wound near the malar process of the maxilla of the same side. The maxillary antrum had been widely laid open, and the man has had a fistula, healed when he came under our observation. He had lost the sight of the right eye since the injury.

R. E., with — 2 D sph., V = 0.

The disc has the classic aspect of post-neuritic atrophy. Moreover, the macular region is covered by abundant pigmentation which doubtless hides the lesions of the choroid, probably small lacerations followed by hæmorrhage (Plate V, Fig. 3). The left eye, equally myopic, has the acuity 1 with — 2 D sph., and presents no lesion.

**Perforating wound of the right orbit; rupture of the choroid, R. E.** (Case 34.)

S. was wounded at Lunéville, Aug. 22. A piece of shell penetrated the right temporal region, a finger's breadth behind the extremity of the eyebrow; it traversed the orbit from above downwards and from behind forwards, coming to rest in the vault of the palate.

Careful study of the course of the missile showed that it had passed outside the optic nerve and behind the eyeball, and it seems to us certain that the globe had not been touched, for two reasons: (1) because the rectilinear course of the projectile traced from the aperture of entry to the orifice of exit passes behind the eye; (2) because such a projectile, capable of penetrating several bony chambers, would certainly have ruptured the eye if it had struck it; further, the optic nerve itself has been spared, for lacerations of the optic nerve, of which we have seen several cases, are accompanied by much more definitely marked damage to the deep membranes.

The left eye is quite normal. The right eye (the affected side) has an acuity of no more than 1/200, not improved by glasses. The ophthalmoscope shows, near the macula, two lacerations of the choroid, parallel and fusiform. The retina is intact, as witnessed by the fine retinal vessels which pass over the choroidal rupture (Plate V, Fig. 4).

**Perforating bullet-wound traversing the malar bones and the nasal fossæ; Choroido-retinitis, L. E.** (Case 35.)

P. was wounded Sep. 15, 1914. A bullet entered under the left eye and came out under the right eye after having traversed the nasal fossæ.

Case examined Nov. 10. The patient then presented no lesions of the anterior segments; the cutaneous wounds have been healed for a long time, conjunctivæ and sclerotics are intact, no ophthalmoscopic lesions. Visual acuity, however, on the right is 1/10, not improved by glasses; on the left it equals 0.

The patient has been regarded as a malingerer and examined in consequence, but it is impossible to prove him in fault. We confined ourselves to observing him. A fortnight later, in the lower portion of the retina of the left eye, pathological pigmentation appeared.

This pigmentation is probably the consequence of small choroidal hæmorrhages, themselves coinciding with slight lacerations disseminated about the uveal tract.

**Traumatism of the malar region; rupture of the choroid; retinitis proliferans, L. E.** (Case 36.)

Q., wounded Oct. 4, was made prisoner and returned from captivity. He had been struck on the face by numerous shell fragments: one had severed the right eye, which is no more than a stump; another fragment penetrated at the level of the left malar bone, which it had fractured. The left eye presents no outward trace of injury; it has not been touched by the fragment of shell. Nevertheless, it bears evidence of great damage. The disc is only recognisable by the presence of two veins, partly covered by traces of proliferating retinitis. Below and to the outer side is seen a large laceration of the choroid, with pigmentation on its margins. It is a large, pearly white plaque, over which pass the retinal vessels. Blindness is complete.

To these cases we will add the following, which is a very good example of the lesions which projectiles producing strong concussion in the bony mass of the face can bring about in the fundus of the eye.

**Traumatism of the bones of the face; rupture of the choroid, L. E.** (Case 37.)

H. was wounded Aug. 22, 1914. The bullet penetrated behind the ascending ramus of the malar bone, two centimetres below the floor of the right orbit. It crossed the right antrum, the palatine vault, and came out on the left cheek, a little above the angle of the mandible. The patient thinks that the shot was fired from about 400 metres.

The loss of vision of the left eye was almost immediate; at the same time severe conjunctival ecchymosis appeared, which remained for a long time.

Examination by the ophthalmoscope shows a large laceration of the choroid, situated in the macular region (Plate VI, Fig. 3). The left eye has also lost central vision. The right eye is normal; its visual acuity equals unity.

With these derangements, due to the concussion of soft parts in relation with the eye, might be compared a very curious case of the effects of airconcussion upon a myope.

**Progressive myopia ; macular choroido-retinitis, R. E.**
(Case 38.)

Aug. 25, C. was thrown into the air by the explosion of a shell which burst alongside him. He remained about ten minutes unconscious. When he came to himself he discovered that he had not a scratch, and went on fighting. Next day there was some pain in the right eye ; however, he continued to fight, firing as before. Sep. 25, he was slightly wounded in the right arm, and sent to Bordeaux. There he stated that the visual acuity of the right eye was rapidly diminishing.

It should be noted that C. was an engraver on glass and that he carried on his calling without needing to wear glasses ; he had done his military service, having left the regiment with the rank of corporal ; he was a very good shot, and only used the right eye.

R. E., with $-13$ D sph. $\frown -2$ D cyl., axis $30°$ V = quantitative, not improved by glasses. The anterior segment and the transparent media are normal. On ophthalmoscopic examination a myopic posterior staphyloma and a macular choroido-retinitis, with large uveal lacerations, are revealed.

L. E. is slightly hypermetropic ; with $+ 0{\cdot}50$ D sph., V = 4/10. This eye presents a slight commencing staphyloma, quite like a typical crescent-shaped myopic staphyloma (Plate VI, Fig. 4).

Jan. 20, his condition was stationary. It was impossible to come to a decision on his case ; so he was sent on convalescent leave in order that, in a few months, one might estimate definitively the condition of the eye, and come to a conclusion about the case. It did not appear to me to be probable that the myopia was entirely consecutive to the concussion of the deep membranes, but it is certain that the macular and peri-macular choroidal lacerations, which have caused the suppression of vision of this myopic eye, have been the result of traumatism by displacement of air. It might be equally considered probable that the

fundus of the eye has lost some of its resisting power under the influence of these lacerations, and that for this reason the eye is elongated, so much so as to reach the figure of thirteen dioptres of myopia. Perhaps myopia existed before the war, but it must have been very slight, since C. was considered an excellent shot, and, when shooting, used only the right eye.

Such are the precise observations, chosen from amongst many others, which we have been able to collect; they appear to us to be worthy to be placed on record, and I consider that they allow us to draw up here, in the form of a synthetic résumé, the four following conclusions.

1. Projectiles, when they penetrate the organism, are capable of producing at a distance serious or irreparable damage to nerve centres, to peripheral nerves, and to the organs of special sense (eye, ear, nose).

2. It is not necessary, to bring about this damage, that the projectile should actually strike the patient; the displacement of the air produced by the explosion of a shell is sufficient to cause the same lesions.

3. In injuries of the face or cranium an exhaustive examination of the visual apparatus should always be made.

4. The injuries are especially lesions of the posterior pole, macular and peri-macular.

Whether the choroid be implicated alone or whether the retina be lacerated with it, it is the macular region and its more or less immediate surroundings which suffer more or less, according to the force of the traumatism, and we might inscribe here this clinical law—*Concussion of the eye without direct shock = macular and peri-macular lesion.*

(2) Hæmorrhages and Detachment of the Choroid.—After ruptures of the choroid, and also with them, for they are closely connected, hæmorrhages of this membrane must be mentioned. The type of these disorders is the expulsive hæmorrhage (Albert Terson) which sometimes happens after the operation

for cataract. To a smaller degree this accident is met with in the serious contusions of the eyeball. The blood is extravasated in the supra-choroidal space and the choroid is lifted up at the same time as the retina. This detachment is distinguished from retinal detachment in that it has a darker tint and is supported by a coagulum, so that it does not undulate with the movement of the globe. In fact, we see the ophthalmoscopic picture yielded by certain sarcomata of the choroid; the fact of the traumatic origin and the use of transillumination will serve to establish the diagnosis.

The blood, poured out at first in the supra-choroidal space, soon diffuses into the anterior layers of the choroid. After a while the blood-clots organise; connective tissue cells appear at the periphery of the clot and soon invade it; numerous capillaries even are formed, which penetrate all the neighbouring tissues, including the retina, and the process ends in what we describe later under the name of proliferating choroido-retinitis.

Many ocular injuries, consecutive to fractures of the orbit, have this fate, for the violent contusion suffered by the globe in such a case is very often accompanied by hæmorrhage, with or without evident lacerations of the two membranes, choroid and retina; several examples are given in the illustrations published in this work, for we have had in our clinic plenty of cases to choose from.

### (2) Affections of the Membranes: (*b*) Retina

It is very true, and Mangini in his thesis has already insisted upon this point, that pure choroidal lesions and unmixed retinal lesions are relatively rare, and that most frequently they are associated. In combination with a choroidal or peri-macular laceration in the form of the arc of a circle, for example, we may find a typical macular retinal lesion, and one frequently meets a laceration affecting at the same time both the choroid and the retina. Nevertheless the pure types are fairly

numerous, owing to the anatomical independence of the choroid (including in this term the pigmented epithelium) and the retina, properly so-called (the distal lamina of the secondary optic vesicle).

According to our views, those authors are quite wrong who have refused to admit the localisation of the rupture in the choroid. WENNEMANN, in the *Encyclopédie française d'Ophtalmologie* (Vol. VI, p. 486), has written that "the choroid can scarcely be torn so long as the sclerotic resists the shock of the violent contusion, and that we often take for ruptures of the choroid what are only simple folds of the retina." Clinical facts invalidate this opinion, and we are convinced of the contrary; Figs. 2 and 4 in Plate V are, in fact, demonstrative. Their value is increased by the fact that they represent photographs of oil-paintings, made by Thorner's method by an artist of great talent, who had no ophthalmoscopic knowledge, and who set himself to paint what he saw, and nothing but what he saw.

The retinal vessels, which in these illustrations cross over the choroidal laceration, belong to an intact retina.

On the other hand, there are pure lesions of the retina independent of any affection of the choroid; they are represented in Plate I, Figs. 1 and 2.

From the anatomico-clinical point of view we shall describe three varieties of retinal lesions: (*a*) Retinitis proliferans; (*b*) Proliferating choroido-retinitis; (*c*) Traumatic detachment of the retina.

The first and the third of these affections are well known and described in all the text-books; we have only to indicate here the peculiarities they have exhibited amongst our patients. The second has not hitherto been described.

### (*a*) *Retinitis proliferans*

Proliferating retinitis is often of traumatic origin, according to SCHIÖTZ in 22 times out of 100, and

one cannot be surprised if, with the great majority of authors, we ascribe it to retinal hæmorrhages. GOLDZIEHER has upheld the view that proliferating retinitis may develop without hæmorrhage, and that it is a disease *sui generis*, resulting in the formation of masses of connective tissue by proliferation of the fibres of MULLER. MANZ, who first described the condition, ascribes great importance to effusions of blood, but does not think that hæmorrhages are essential to the proliferation of the retinal tissue. It was LEBER who insisted upon the important rôle played by extravasations of blood in the pathogeny of the affection. We believe that he is right; they have been the basis of all the cases of proliferating retinitis we have seen, and in SCHIÖTZ' statistics, out of 121 cases, these hæmorrhages were only lacking four times. Besides, it is sufficient to inject blood into the vitreous body of animals, as PROBSTING has done, to see, associated with the hæmorrhage, the proliferation of the connective tissue of the retina; the development of the retina attains in a few weeks three or four times the normal thickness of the membrane; three or four months after the injection the retina is in places transformed into strings of connective tissue, containing, in the thickness of fibrillar masses, red corpuscles, more or less altered.

These anatomical examinations, based on experimental facts, agree moreover with the results yielded by some examinations of the human eye, cases of retinitis proliferans; the examinations of MASSY, PURTSCHER, and VERKLI have shown the existence of a membrane of fibrillar connective tissues, adhering at certain points to the optic disc and the retina. MANZ, whose case was of four years' duration, did not find hæmorrhagic débris, probably because of the long duration of the affection. DENIG, PURTSCHER and VERKLI observed, in the masses of more recent formation, numerous traces of blood (lymphocytes, disorganised red corpuscles, numerous leucocytes). The external layers of the retina have often preserved their normal structure; the internal portions, the fibres of MÜLLER, are those

which have proliferated. The pigment epithelium is intact, so that the affection does not establish artificial adhesions between the two layers developed from the secondary optic vesicle, *i. e.*, between the pigmented epithelium and the retina, properly so-called. The result is that the fibrous contraction of the bands of connective tissue, of which we have just spoken, easily separates these two layers, which are simply apposed to one another, and produces what we call, clinically, detachment of the retina—*i. e.*, separation of the two layers of the optic vesicle.

Retinal detachment is in consequence frequent in proliferating retinitis.

Such are the general data which apply to this affection; it often occurs in relapsing spontaneous hæmorrhages of the retina. It is equally common, and indeed it should be looked for, after the lesions of the eyeball which accompany choroidal and retinal hæmorrhages, as well as effusion of blood into the vitreous body.

We have observed this very frequently, and we will now apply ourselves to the task of portraying the characteristics of the cases we have observed.

*Symptomatology.*—The symptoms at the onset of proliferating retinitis are those of hæmorrhages, and, as in the traumatic cases the affections are well marked, we find usually not photopsiæ and scotomata, but complete loss of vision. As the blood becomes gradually absorbed vision may return, and sometimes be even relatively good, with quite extensive lesions; this depends evidently on the seat of the retinal disorders visible with the ophthalmoscope, and also on the seat of the affections which cannot be seen, for a very slight alteration of the macular region is sufficient to diminish or suppress central visual acuity in a subject whose lesions appear to be of slight extent.

Moreover, it is by no means rare to find that diatheses or infections with which the subject has been attacked contribute to complicate the accidents by pouring toxins or infectious agents over the retinal laceration. The soldiers whom we have examined, in general healthy

and vigorous, have perhaps been less exposed to such complications than the generality of patients; but it has been evident to us, on several occasions, that syphilis has interfered with the normal evolution of the anatomical disorders.

The natural progress of these affections leads to the organisation of connective tissue, and for the same reason, being subject to the general laws of pathological anatomy, to contraction. This contraction has the great detriment of dragging on the retina and detaching it; sometimes it may even produce a tear in the new-formed membranous veil, thus laying bare a healthy portion of the retina, which is rendered capable of discharging its functions. GONIN, in an excellent article in the *Encyclopédie*, reports the history of a case in which the central visual acuity came back to 5/10 by reason of a laceration occurring in the macular region; the patient related how he had seen, in the space of a very few days, as it were a window open in the centre of the thick veil which covered his eye.

After having described classic retinitis proliferans, such as has always been present to our minds while examining our wounded patients, we are of opinion that we should call attention particularly to a variety which we have ascertained to follow fractures of the orbit. It is a matter of an affection, very different on the whole, from those described by authors. We propose to call it "proliferating choroido-retinitis," and we proceed to give the description of it.

### (β) *Traumatic Proliferating Choroido-retinitis*

Choroido-retinitis follows, not hæmorrhages into the vitreous body, such as the relapsing hæmorrhages of adolescents, but hæmorrhages of the retina and choroid due to lacerations.

This traumatic proliferating retinitis results from the organisation of effusions which are situated outside the vitreous. Here is a characteristic which distinguishes this affection from the proliferating retinitis compli-

cating the relapsing hæmorrhages of the vitreous of adolescents. There the disorders belong to the vitreous; a retinal vessel bleeds in the eye, the first intraocular epistaxis is absorbed, the second leaves behind some traces, and after the third or fourth relapse the effused blood ends by becoming organised, by the aid of the elements of the most internal layer of the retina (fibres of MÜLLER, perivascular mesodermic tissue), which, when irritated, proliferates and gives birth to the great fibrous tracts which the classic authorities have taught us to recognise, and which trespass, not only on the most internal parts of the retina, but also on the peripheral layers of the vitreous body.

The conditions of the proliferating choroido-retinitis of our wounded are quite otherwise; in their case there is no relapse, the vessels which bleed do not proceed from the retina, nor do the proliferation and post-hæmorrhagic organisation of the connective tissue; the seat of the trouble is not retino-vitreous.

Under the influence of shock or of ocular concussion a rupture of the uveal tract and of the retina has taken place; there has been a more or less extensive effusion into the meshes of these membranes. Is it small in quantity? Then it will be absorbed, and the choroido-retinal scar will take on the appearance so well known as atrophic and pigmented choroido-retinitis. Is the amount of blood more considerable? The vitreous may then be implicated, but the clots which are in its meshes rapidly disappear. But the hæmorrhage, on the contrary, which in these cases is present in the whole thickness of the retino-choroid and in the retino-vitreous space, experiences much difficulty in becoming absorbed; it becomes organised, at the same time provoking irritation of the connective tissue of the uveal tract in the region of the rupture. The connective tissue proliferation takes place at its expense, and results in the formation of fibrous tracts, which, at first slight, might be taken for proliferating retinitis, properly so-called. We see therefore that traumatic proliferating retinitis differs much from the classic type as

regards its situation. We have to deal, in our soldiers, with *a proliferating choroido-retinitis*, the choroid participating in fact in its formation as much as the retina, and even more than the retina itself.

We are dealing, therefore, with a choroido-retinal cicatricial process secondary to the rupture or laceration of these membranes, and this statement will explain why the papillo-macular region should be the habitual seat, since it is also that of the traumatic choroido-retinal disorders sequent to orbital fractures.

One of the appearances which best demonstrates this is offered by the disc when a projectile has caused avulsion of the optic nerve. The papillary hole which follows this tearing-out is filled up little by little by a proliferating connective tissue formation in which the peripapillary uveal tract, infiltrated by great hæmorrhagic patches, participates with the papilla (see Plates III and IV).

Being cicatricial tissue, the result is that traumatic proliferating choroido-retinitis, once organised, cannot be modified. The loss of vision, more or less complete, the modifications of the visual field which follow, are definitive. Retinal detachments, which are caused by secondary traction of the retina towards the vitreous, by the contraction of the fibrous vitreo-retinal cords, are common in proliferating retinitis, since in this affection the disorganisation concerns the deep layers of the retina, and especially the uveal tract, to which this membrane is simply applied. But with our soldiers the cicatrix involves both retina and choroid; the organised patches intimately attach the retina to the underlying ocular membranes, and thus prevent slow detachment.

*Ophthalmoscopic appearances.*—From the ophthalmoscopic point of view its characters are as follow: a greyish white mass surrounded by a zone more or less extensive, sometimes very large, blackish, pigmented (Fig. 44); this mass is raised, a fact which testifies to the proliferation of the connective tissue; the retinal vessels are seen to pass over it, turning out

of the direct line to do so (Plate IV, Fig. 3); vessels too pass underneath, some are seen to perforate it, forming loops which project forwards (Plate III, Fig. 2).

In Plate IV, Fig. 1, below the atrophied disc can be distinguished a raised white patch, upon which climb vessels emerging from the papilla and making a visible

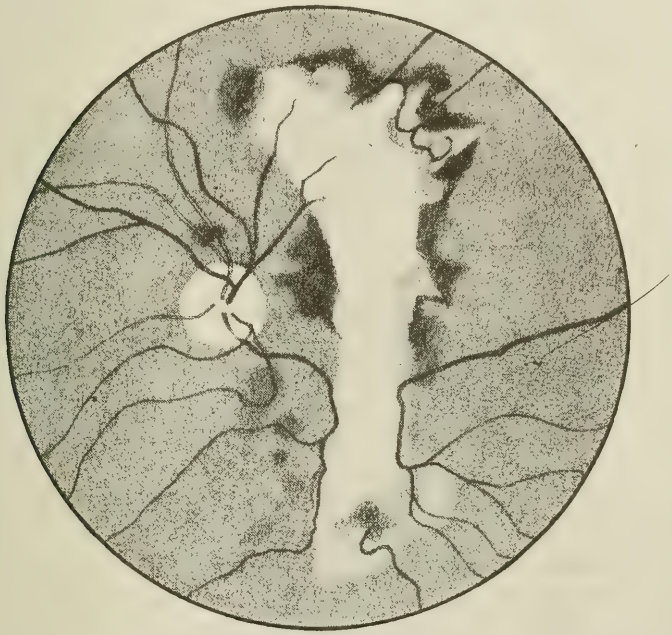


FIG. 44.—Fracture of the left frontal sinus; eyeball contused by the inferior wall of the sinus thrust downwards. Proliferating retino-choroiditis of the posterior pole implicating the macular region.

bend, precisely at the moment when they mount upon this elevation; whilst these retinal vessels are manifestly situated above and in front of the plaque of proliferating newly-formed tissue, other vessels traverse the plaque in the middle of its substance, and others pass beneath.

The two figures (Fig. 35; Plate III, Fig. 1, papillary avulsion) are amongst the most interesting of our

collection; they have to do with a total or subtotal avulsion of the disc.

The first deals with a partial tearing-away, affecting the upper part of the papilla (inverted image); the half of the disc which has been torn away is covered by new formation, whence the vessels spring; it is remarkable that this fibroid mass is not everywhere sufficiently prominent to fill the fossa created by the papillary avulsion; it is only exuberant in its inferior portion; at the upper part it is still upon a plane deeper than the rest of the fundus of the eye. The other figure is a truly admirable example of total avulsion of the papilla, a papillary detachment which is accompanied by two lacerations starting from the macula, the one above and to the outer side, the other down and in; there is a third tear in the macular region. All around the disc the choroido-retinal lacerations have proliferated, but the excavation has not been filled up; there remains a cavity recalling the ophthalmoscopic image of certain cases of chronic senile glaucoma; there has been a true avulsion of the papilla in the correct sense of the word.

Often the laceration of the choroid and retina, which entails the proliferation, is seated exclusively in the macular region (Plate IV, Fig. 2); the mass of new formation then has no direct relation to the larger vessels; it takes the form of a fibrous "cake," irregularly star-like (Plate III, Fig. 2); or of the arc of a circle, (Plate IV, Fig. 4); frequently around this fibrous "cake" is found a pigmented zone, indicating the considerable participation of the uveal tract in the proliferation.

The figures which represent this proliferating choroido-retinitis, in addition to all those of Plates I, II, III and IV, have been drawn from nature by M. Pesme, student of medicine, hospital orderly in the service, to whom we desire here to render thanks.

COMPARATIVE TABLE SHOWING THE DIFFERENCES BETWEEN PROLIFERATING RETINITIS AND TRAUMATIC PROLIFERATING CHOROIDO-RETINITIS.

| *Retinitis Proliferans* | *Traumatic Proliferating Choroido-retinitis* |
|---|---|
| Proliferation due to organisation of effused blood; may be produced without previous hæmorrhage. | Always consecutive to a hæmorrhage and a rupture of the deep membranes. |
| Membranes with multiple prolongations; appearance of a spider's web spread over a large portion of the fundus of the eye. | Fibrous plaque, more localised, of a more regular thickness. |
| Membranes translucent in certain points. | Everywhere opaque. |
| Projections ending free in the vitreous. | Simple relation of propinquity with the vitreous body. |
| Masses, pedunculated, polymorphous, with uneven surface, outline well marked. | No very prominent masses in the vitreous body; even surface, projecting moderately. |
| Situated in all parts of the retina. | Much more common in the macula, the disc and its circumference. |
| Focus of pigmentation very frequently around the membranes. | Foci of pigmentation very frequent. |
| Often complicated by detachment of the retina, due to traction of the vitreous bands. | Is not accompanied by detachment consecutive to the proliferation, which, on the contrary, attaches the retina to the choroid. |

### (γ) *Traumatic Detachment of the Retina*

In this class of retinal detachments we may admit several varieties which can be succinctly enumerated thus.

(1) Detachment by subretinal hæmorrhage.

(2) Detachment by post-traumatic retraction of the vitreous body.

(3) Detachment which results from the cicatricial contraction of a wound.

(4) That which follows a loss of vitreous.

(5) That which results from concussion at a distance, with or without laceration of the retina.

We have met with all these varieties, and we have noted forty retinal detachments amongst our hospital cases; a very frequent form is the detachment by concussion.

The shock upon the eye causes a subretinal hæmorrhage and a laceration of the retina and choroid; three months afterwards one finds a large plaque of atrophy and not a detachment of the membrane.

We have rarely met with this affection in the cases of foreign bodies of the orbit; amongst our cases we can recall only one (Case 24, Fig. 30) in which a piece of shell injured the external orbital process, resulting in a profuse vitreous hæmorrhage, which after a certain time allowed large detachments to be seen, one peripheral to the external equatorial portion, the other in the macular region. There was a shell fragment below the eye; this fragment must have contused the organ and a great part of the derangements should be attributed to direct shock. But it should also be remarked that a violent contusion, the fracture of the external orbital process, must have set up in the eye concussion quite sufficient in itself to produce the detachment of the retina.

The number of cases of retinal detachment caused by simple concussion at a distance is not very considerable, but we believe nevertheless that we ought to draw attention to this type of disorder because of this special pathogeny.

We have four cases to quote: the two first are Cases 15 and 16, in which the projectile traversed the facial mass from one side to the other, without lesion of the eyeball, and provoked, in the first, retinal detachment at the inferior part of both eyes, in the second, detach-

ment at the infero-external portion of one eye. The two other cases are identical as to pathogeny, although they deal with two fractures of the external wall of the orbit, which have brought about total detachment of the retina on the side of the fracture.

In relation to these four cases, moreover, we can bring forward two others in which there was no fracture of the orbit, but, as a result of simple displacement of air, caused by the near explosion of a shell, the two cases were affected, one on the right side, the other on the left, with detachment limited to the inferior portion of the retina, without direct shock to the globe.

We have considered it our duty to chronicle this variety of traumatic detachment here with some details, for it is less common than the other forms of this condition.

We do not think we need insist upon the varieties which result from subretinal traumatic hæmorrhages, nor upon the detachments consecutive to fibrous organisation of the vitreous body; what we have said on proliferating retinitis, and all that the authorities have taught on this subject, will certainly be prominent in the mind of the reader.

Practical considerations on the prognosis and treatment of this kind of lesion will be found later in the book. (See Treatment of Fractures of the Orbit and their Complications.)

### E.—Traumatic Enophthalmos .

Enophthalmos is a symptom which occurs in a certain number of varied conditions, and too many authors have sought to give it a single pathogenesis, as if it were a question of an affection always the same and well defined.

Sinking of the eye in the orbit may happen under a great number of circumstances, all different :—

(1) When the means of suspension, passive or active, of the eye are torn or paralysed; the capsule

of Tenon ruptured; the oblique muscles paralysed; or when the recti muscles are retracted.

(2) When the cervical sympathetic is paralysed by too prolonged action or excitation.

(3) When after a profuse hæmorrhage of the orbit or chronic inflammation of the cellulo-adipose tissue there occurs cicatricial retraction of the retro-bulbar tissue.

(4) When trophic troubles occur, involving absorption of the cellulo-adipose tissue.

(5) When the orbital cavity is enlarged by a fracture which produces a depression of any one of its walls.

The fact is that enophthalmos may occur whenever there is default of any of the forces which maintain the eye in the exact equilibrium which is normal to it. These forces are the following: (1) the traction backwards of the recti muscles and the traction forwards of the oblique muscles; (2) the capsule of Tenon and the smooth-fibred muscle of Müller, which represent an active element capable of being immediately modified by the excitation or the paralysis of the sympathetic; (3) the cellulo-adipose cushion upon which the eye rests; (4) lastly, the bony cavity whose firmly fixed walls give stability and rigidity to the visual apparatus.

It is obvious that these diverse conditions of the ocular equilibrium, when modified, may bring about enophthalmos, and that each ætiological variety corresponds with the clinical varieties we have met with amongst our wounded.

We shall pass in review each of these varieties, laying under contribution what has been said by the different writers who have busied themselves with the question, and utilising the cases we have collected.

(1) The enophthalmos which results from defective equilibrium between traction of the recti muscles behind and the obliques in front is the rarest form; we do not think it exists in the science of ascertained facts; *a priori*, it is evident that paralysis of the two

obliques should be followed by a retreat of the eyeball; but, clinically, paralysis of the pathetic and of the branch of the oculo-motor destined for the inferior oblique must be extremely rare, and this variety should be looked upon as so exceptional that in ordinary practice it need not be considered.

It is, however, not only the muscles, the active ligaments, which maintain the eye in position; there is also the action of the aponeuroses and passive ligaments in the ocular enarthrosis; the means of suspension may be torn or dislocated by traumatism. PICHLER admits in the ætiology of the affection the rupture of the *septum orbitale;* KILBRUN (*Archives d'Ophtalmologie*, 1902) reports the case of a man who, ten days after having fallen from a sledge, presented ptosis by enophthalmos, and explains his case by laceration of TENON'S capsule, or its ligamentous appendages.

Such ætiological conditions must be very rare; we have not seen them amongst our patients, and in the great majority of cases it is to the other mechanisms, previously enumerated, that we must look for the processes capable of explaining enophthalmos.

(2) The paralysis of the unstriped muscle of MÜLLER is a cause of enophthalmos, and it will be fitting here to give some anatomical and physiological details.

This muscle, upon which, after MÜLLER, SAPPEY has insisted, is a layer, fibrous in appearance, but in reality muscular, extending transversely from the internal to the external part of the orbit, continuous below with the adherent border of the tarsal cartilage and giving insertion above to the levator palpebræ and to the subjacent prolongation of the orbital fascia. It has a fixed origin and a mobile insertion, like all muscles; its origin, by its union with the levator, corresponds to the apex of the orbit and its insertion is the adherent margin of the tarsal cartilage.

Into its constitution enter a great number of laminated fibres and of elastic fibres, but these are only

accessory elements; the fundamental elements are the unstriped muscular fibres.

The bundles which form the median portion are directed from above downwards, the divisions interlacing and forming a sort of network with irregularly elliptical meshes. This muscle represents a segment of a hollow sphere which surrounds the eye over a large portion of its area.

There is also a MÜLLER'S muscle in the lower eyelid; its attachments are, on the one hand the deep surface of the palpebral expansion of the tendon of the inferior rectus muscle, on the other hand the convex margin of the tarsal cartilage; at the level of the inferior fornix of the conjunctiva it splits into two layers: one, palpebral, which goes to the tarsal cartilage, the other going between the bulbar conjunctiva and the eyeball.

MÜLLER'S muscle contains groups of nerve-cells analogous to ganglionic nerve cells, in such a manner that it possesses its own innervation, independent of the oculo-motor which innervates the levator palpebræ.

It is innervated by the cervical sympathetic. When this nerve is divided MÜLLER'S muscle is paralysed, and, the eye sinking back into the orbit, the patient has enophthalmos. Excitation of the sympathetic, by exaggeration of the action of the muscle, produces exophthalmos. It must therefore be admitted that, according to physiology, the unstriped muscular fibres, which form the muscle of which we are speaking, surround the eye, pass behind its equator, and, in contracting, push it forwards. The anatomical description given above, although strictly according to the authorities, does not make the action of the muscle clear to the comprehension; it is more than probable that smooth muscular fibres exist right into the capsule of TENON, facing the posterior hemisphere of the ocular globe, for without them we confess that we fail to understand the physiological action of the muscle of MÜLLER.

The description which the anatomists give shows

why excitation of the sympathetic, acting upon the muscle, increases the palpebral opening, whilst section of the sympathetic closes that opening; but it in no way enables us to understand why the subject should become exophthalmic in the first case and enophthalmic in the second.

We present these reflections to the anatomists and physiologists in passing.

Here we publish a case of enophthalmos due to section of the cervical sympathetic by shrapnel.

**Section of the sympathetic by a shrapnel ball; enophthalmos; Claude Bernard's syndrome; recovery.** (Case 39.)

P. L., aged 22 years, Infantry, was wounded Sep. 5 by two shrapnel balls. One struck him in the arm, the other in the neck, at the level of the fourth cervical. It

Fig. 45.

penetrated the right side at the posterior border of the sterno-cleido-mastoid, and taking a horizontal course, came to rest in the left carotid region.

The orifice of entry is narrow and has not bled, but immediately after the injury L. spat blood. Pharyngeal hæmorrhages occurred for several days; at the same time the patient swallowed with difficulty and experienced a burning sensation in the pharynx. The pharynx, therefore, has been traversed by the ball. The left carotid

region, where it is lodged, presented for some time a lively inflammatory reaction, but the ball was soon discovered by palpation, and extracted by an incision similar to that used for ligature of the carotid.

It was then that the case was sent to us. There is marked enophthalmos of the right eye. The palpebral fissure is narrowed, the pupil in a condition of miosis. L. states that his eye has been very red, that he has had a sensation of gritty particles in the conjunctiva, and that there was running of the eyes directly after the injury, but that these symptoms have disappeared.

Visual acuity equal to unity; visual field intact.

The left eye is healthy. There is nothing abnormal to be found in the spheres of action of the glosso-pharyngeal, pneumogastric, spinal accessory, and hypoglossal nerves. The enophthalmos rapidly diminished, and the case only presented a slight narrowing of the palpebral fissure when he was discharged, Dec. 31, 1914.

In this case is realised, in the clearest manner, the experiment of POURFOUR DU PETIT and of CLAUDE BERNARD; a well-known fact is noted, to wit, that the greater portion of the ocular results of section of the sympathetic are transitory; of this number is the enophthalmos, which, strongly marked at the time of the accident, had completely disappeared four months later. It must not be thought that, under such circumstances, the enophthalmos is only apparent, and due solely to the peculiar appearance given to the eye by the narrowing of the palpebral aperture; the enophthalmos is very real. The eye is carried backwards in a very definite manner, as though one of the forces which draw it forwards had suddenly failed to act. It is this action upon the globe, well demonstrated by physiologists and by clinical experience (as our case testifies), which the anatomical study of MÜLLER'S muscle would not teach us to foresee.

(3) Enophthalmos, due to paralysis of MÜLLER'S muscle, is rapid—so to speak, immediate—when the cervical sympathetic is divided. In the classic experiments of POURFOUR DU PETIT and CLAUDE BERNARD,

retraction of the eyeball is part of the paralytic syndrome of the cervical sympathetic, but this enophthalmos, which the surgeon who resects the superior cervical ganglion for the cure of glaucoma, for example, (JONNESCO, ABADIE, etc.) produces in spite of himself, is still very rarely observed clinically as a sequence of accidents which happen to the orbit and its contents. The case we have just reported is, perhaps, unique in science.

The nervous theory of enophthalmos should be extended to cover the trophic disturbances which lesions of the sympathetic entail upon the nutrition of the cellulo-adipose tissue upon which the eye rests. When vaso-motor innervation is at fault the orbital tissues are badly nourished, become less solid, and the eye follows them in their retraction; this theory has already been defended by BEER in 1893. In a patient, kicked by a horse, without the orbital walls being enlarged or driven in, there appeared a well-marked enophthalmos which this writer attributed to rarefaction of osseous tissue. PURTSCHER has also adopted this view; he very properly remarks that there is only true enophthalmos in cases where there is no depression of the orbital walls or cicatricial bands; true enophthalmos, strictly speaking, as in our cases, Nos. 40, 41, 42, is that which is produced in an orbit in which the cellulo-adipose mass has lost its normal volume as a sequence to faulty innervation.

The cases in which the appearance of profuse hæmorrhage has been noted at the moment of traumatism, causing at first exophthalmos, and afterwards enophthalmos by cicatricial organisation of the clot, are no longer to be considered pure cases. These pure cases of enophthalmos, those which we may look upon as cases of essential enophthalmos, are those which correspond to simple atrophy of neuro-trophic origin. When the enophthalmos is preceded by a clot becoming organised and retracting in the orbit, or still more when cellulitis has previously developed, a particular variety is in question, having, in a way, a

mechanical origin; this form is rare, we have not seen it in either civil or military practice. The mobility of the globe, well preserved in general, and the rapidity with which the enophthalmos appears do not accord with the organisation, always leisurely, of cicatricial tissue. COHN is the sole author who has insisted upon the limitation of the movements of the globe, which he found in one case adherent to the surrounding parts. With all our patients, as in all the cases of which we have been able to read the reports, the ocular movements have preserved all the freedom compatible with the vicious position occupied by the organ in the orbit.

It results from what has been said that the great majority of cases of sympathetic enophthalmos should be explained by trophic derangements due to disorders bearing upon the innervation of the orbit, and we do not see wherefore certain authors maintain absolutely that a fracture of the orbit exists (MORAX, CHAILLOUS). Doubtless in violent orbital traumatism, by contusion most frequently, a fissure will exist in the orbital walls, and, even in fractures by projectiles of war, the lesion will be always more or less marked; but in the cases of essential enophthalmos, of true enophthalmos, the osseous lesion will hold an accessory and relative place; otherwise, in all orbital fractures in military surgery, there would be enophthalmos. We are confronted by quite different clinical facts, because out of several hundreds of orbital fractures we have only been able to find four cases of traumatic enophthalmos. These are fractures affecting the ciliary ganglion or the carotid plexus which enters the orbit with the ophthalmic artery, and they are accompanied by true enophthalmos. It is not the fracture which matters; what does matter is the lesion of nerves capable of interfering with the nutrition of the retro-bulbar cellulo-adipose tissue.

Here are three unpublished cases of traumatic enophthalmos from trophic troubles.

**Fracture of the right orbit ; traumatic enophthalmos consecutive to trophic troubles.** (Case 40.)

H. G., Infantry, wounded at M., July 5, 1915, by a fall from the edge of a trench, due to the explosion of a shell. He lost consciousness for three or four minutes; he was immediately sent to be treated at T. Sent back to the front twenty days later, he had two successive attacks of giddiness, and came viâ Chalons to Bordeaux, where he was admitted Sep. 5, 1915.

Case-sheet on entry : " Fracture of right orbit from fall on the right orbito-ocular region, with wound over the superior orbital margin and detachment of upper eyelid."

*Examination.*—March 12, 1916, the right palpebral fissure has its opening diminished by retraction of the eyeball. This latter, in fact, is sunk at least 4 mm. This enophthalmos is not the consequence of depression of the walls of the orbit, as is evidenced by radiography. It is due, it seems, to trophic disturbance of the orbital contents, thus realising the classic type of traumatic enophthalmos by derangement of nutrition.

There is paresis of the external rectus muscle, the superior rectus, and the inferior oblique, causing well-marked homonymous diplopia.

There is probably a nerve lesion caused by the fracture having injured at the apex of the orbit, in the sphenoidal fissure, filaments of the sympathetic at the same time as the motor nerves.

The right eye has normal tension. The pupil reacts perfectly, directly and consensually; there is no lesion of the deep membranes or of the transparent media. Acuity equals 7/10 with a spherical convex of + 1 D.

The left eye is normal, V = 10/10.

This condition has remained stationary up to to-day (May 25, 1916).

**Contusion of the left orbital region, probably fracture ; traumatic enophthalmos of the left eye : consecutive trophic troubles.** (Case 41.)

E. R., wounded Nov. 16, 1915, at bombing exercise, at H. Sent by medical board Sep. 24, 1916.

*Examination.*—R. presents at the level of the left upper eyelid a cicatricial wound resulting from the violent

traumatism suffered by the orbito-ocular region at the moment of bursting of the grenade. The soft parts of the orbit, including the globe of the eye, have been severely contused by displacement of air; as concerns the orbit, there have resulted trophic troubles ending in the disappearance of the retro- and circum-ocular adipose cushion, and producing sinking of the globe in the orbital cavity.

This enophthalmos, very marked, is accompanied by ptosis of the upper eyelid, due partly to paralysis of the levator, partly to the retraction of the globe.

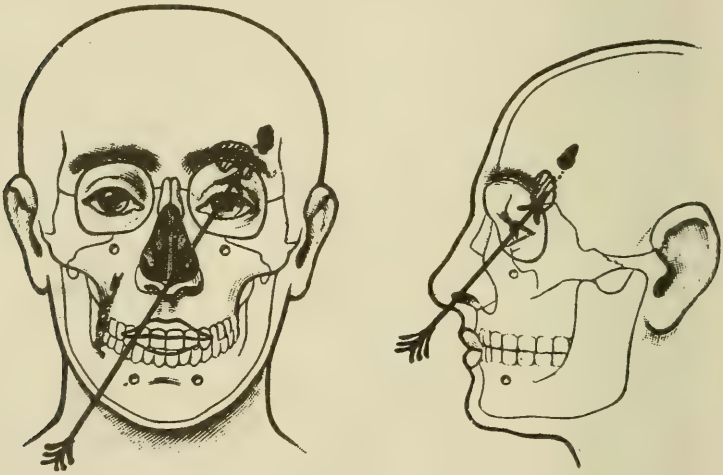


Fig. 46.

Radiography shows that there is no intra-orbital projectile. But, by touch alone, it is easy to localise in the left fronto-parietal region a large piece of shell, encrusted in the bony wall (Fig. 47). It is impossible to make certain by radiography if there is a fracture irradiated to the vault of the orbit, recollecting the interval of time between the date of the injury and our examination. The presence of the fragment shows clearly, however, that the left orbital region was in the sphere of action of the traumatism.

The left eye is on the way to atrophy. There is a total detachment of the retina, with the exception of a small segment of the infero-internal region.

Ocular tension lessened : T — 2.

Right eye normal, V = 10/10.

No disturbance in the transparent media; examination of the deep membranes reveals to us no lesion.

**Paralysis of the external rectus and consecutive trophic troubles (enophthalmos).** (Case 42.)

R., Dragoon, kick of horse, Nov. 28, 1897, under the following conditions. Wishing to pick up a snaffle lying on the ground in the stable, about 50 cm. from his mare,

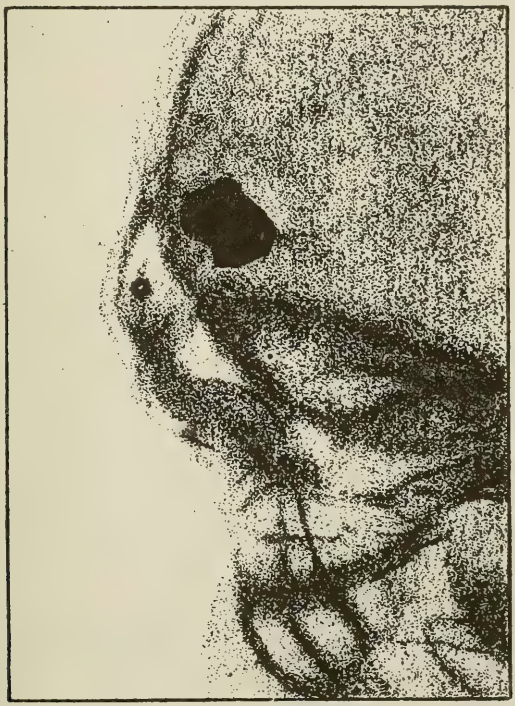


FIG. 47.

at the moment when he was about to incline, the body being almost in the vertical position, save for a slight bending backwards of the back, R. received a kick a little below the right eye, which caused a wound about 3 cm. long by 5 mm. wide; he then fell heavily upon his back, making a deep wound of the occipital region, about a centimetre in diameter. Nevertheless, he did not lose

consciousness, and was assisted by two comrades to walk to hospital.

In hospital the patient presented only a well-marked palpebro-conjunctival ecchymosis, in addition to the two wounds which were sutured and dressed.

At the end of a month, the wounds being cicatrised, dressings were discontinued; at this date, he complained of diplopia.

At the beginning of Jan. 1898, the date when he came to us, he had evident signs of paralysis of the external rectus of the right eye, with contraction of the antagonising muscle; further, the face is thinner on the damaged side, and the eye suffers from enophthalmos: V = 1. Emmetropia both sides.

No trouble of accommodation. Diagnosis: basilar paralysis of the sixth nerve.

During the whole of the year 1898, R. was kept under observation, in the hope that, if the nerve were simply contused, all would come right; but it was not so. With the object of remedying the trophic trouble, thirty sittings of electrisation with continued current were given. The trophic disturbances were a little improved.

In Jan. 1899, more than a year after the accident, the patient had, besides his enophthalmos, a very unbecoming strabismus which caused diplopia, always very extensive and very tiresome.

To remedy the enophthalmos and correct the strabismus, Feb. 7, 1899, we performed the double operation of capsular advancement of the external rectus and tenotomy of the internal.

The result of this operation was excellent in this sense, that the patient had no longer strabismus, and easily remedied, by turning the head, the diplopia which still existed in the right temporal region. He easily walked with the head upright, looking straight ahead without seeing double, and his enophthalmos had disappeared.

He still had complete paralysis of the external rectus of the right eye, but the inconveniences of this paralysis are reduced to the minimum.

(4) We arrive at last at a variety of enophthalmos which is really a false enophthalmos; it is that which depends upon a depression of one of the walls of

the orbit, causing enlargement of its cavity; it is, indeed, a "false enophthalmos" if we reserve the name "true enophthalmos" to that which results from trophic troubles; but in military surgery it is the form most frequently met with. We put forward here three good illustrations.

The eye, acted on by gravity, may fall into the maxillary antrum, or be thrust there by the wounding instrument itself. The cases of SMETIUS DE LEDA, of BECKER, of LANGENBECK, fall into the same category. It is also by fracture that LANG explains his case; he thinks that the orbit is enlarged by traumatism, and that the eye sinks in under atmospheric pressure; NAGEL in his case accepts the same explanation. The reality of this mechanism allows of no doubt. NEUBEN, however, is wrong in wishing to apply it to every case. It will not do to maintain that there is always depression of the orbital walls in enophthalmos: from the violence of the shock there may be frequently an osseous fissure; but, as we have already said, it is not this fissure which is the cause of the sinking in of the eye.

We must distinguish, therefore, two principal varieties of enophthalmos—

(1) True enophthalmos, properly so-called, due to the nervous troubles which we have placed in evidence, following many writers, notably DR. DAULNOY and PROF. ROHMER.

(2) False traumatic enophthalmos from enlargement of the orbital cavity, of which we have collected three cases which we report here.

**Fracture of the left orbit; large piece of shell in the right orbit; atrophic and pigmentary choroido-retinitis.** (Case 43.)

Commandant R., Infantry, wounded Sep. 14, 1914, at C., by a shell. From F. he was sent to us, and examined Oct. 26, 1915.

*Condition.*—The shell fragment has penetrated the infero-external portion of the left orbit, where there is a scar 3 cm. in length, direction vertical, the upper extremity of which starts from the external canthus. The projectile is

lodged in the right ethmoido-orbital region, having followed a path from left to right and from before backwards. It has therefore traversed, first, the floor of the left orbit; second, the left orbit; third, the left nasal fossa and the septum; fourth, the right ethmoid and the internal wall of the right orbit.

The radiogram of Nov. 14 shows the presence of a large piece of shell, 3 cm. long by $1\frac{1}{2}$ wide, two-thirds of which are enclosed in the ethmoid and the other third projects into the right orbit, after having pierced the internal wall.

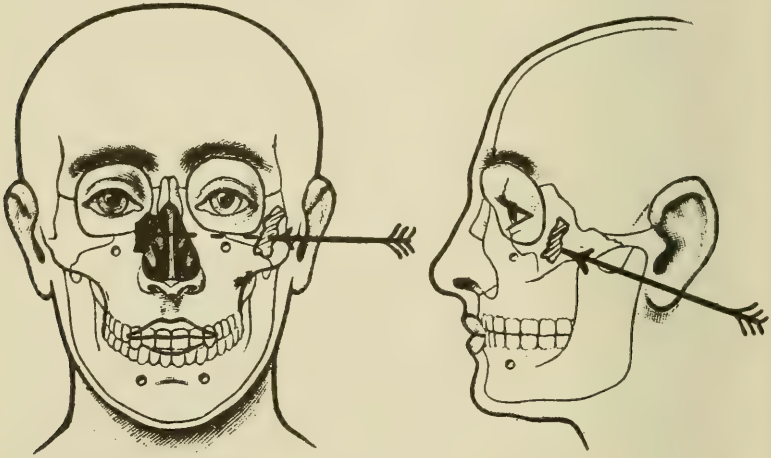


Fig. 48.

Commandant R. refused all interference; moreover, the foreign body had been well tolerated for sixteen months.

From the orbito-ocular point of view, we note the following—

(1) A fracture of the infero-external portion of the left orbit, from which a splinter 1 cm. long was extracted eight days after the injury: a depression of the floor of the orbit has resulted, with sinking in of the eyeball (traumatic enophthalmos from orbital fracture).

(2) Lesions of the left eyeball. This eye, normal exteriorly and with extrinsic musculature intact, presents on the crystalline lens a slight, well-defined opacity, situated above and to the outer side. The disc is a little reddened, its contours blurred and ill-defined (neuritis and perineuritis). The macular region on careful examination is

found to be œdematous, thus explaining the metamorphopsia of which the patient complains. At the lower part, near the equatorial region, is a large patch of atrophic and pigmented choroido-retinitis, remains of rupture and hæmorrhage of these deep membranes.

L. E. $V = 1/10$.

(3) On the right, we note a proliferating macular choroido-retinitis surrounded by pigment, causing a central scotoma in the visual field and lowering the acuity to 1/100 (Plate IV, Fig. 2).

The right eye shows slight external strabismus, due to disuse. There exists a diplopia in which the false image is very dim, but extremely annoying, especially when looking downwards (paralysis of the left inferior rectus muscle).

**Fracture of the left orbit; traumatic enophthalmos; total detachment of the retina.** (Case 44.)

G. Sergeant, Zouaves, wounded July 1, 1916, in the left orbital region, by shell fragment. Treated at St. M. and at Ch. Admitted July 18, 1916.

The projectile has caused a large fracture of the superior orbital margin and the external region of the left orbit. The superciliary arch is completely smashed in over the external two-thirds and the gap in the bone is prolonged to the ascending process of the malar bone.

The upper eyelid is in a condition of ptosis owing to paralysis of the levator, and also because of the retraction of the eyeball.

The latter, in fact, is pushed back into the orbit, and the enophthalmos measures 4 or 5 mm. No movement is possible by reason of the extreme relaxation of the extrinsic muscles.

The pupil is dilated to the maximum. The anterior segment of the eye is intact; ophthalmoscopic examination reveals total detachment of the retina, explaining the hypotony of the eye.

Vision equals 0.

The enophthalmos may be explained either by the depression of the orbital walls or by the retraction of the retrobulbar adipose cushion. Depression of the walls is the more probable because a large piece of shell was extracted, two

days after the injury, from behind the eye against the inferior wall. Besides, the radiogram shows this depression (Fig. 49).

Sep. 2, 1916, section of the four recti muscles, an attempt to palliate the retraction of the globe, gave no result.

Sep. 11, restoration of the superciliary arch was attempted by means of a graft of costal cartilage; a piece six centi-

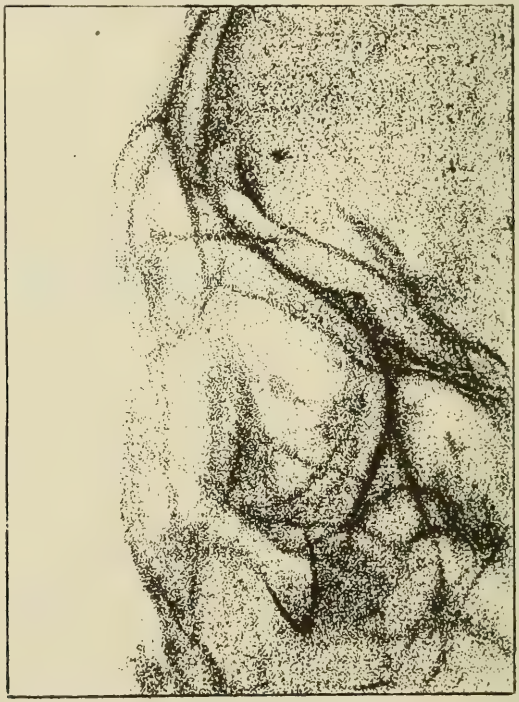


Fig. 49.

metres long was removed from the rib, and at the same time a portion of pre-costal adipose tissue.

The cutaneous orbital cicatrix was carefully excised; then, by splitting the subcutaneous layer of tissue, a cavity was made, large enough to contain the cartilaginous and fatty grafts. Suture of the superficial layers by silk-worm gut.

Post-operative progress entirely satisfactory; the wound healed by first intention, and a fortnight later the restora-

tion of the superior wall of the orbit was as successful as possible. But as the enophthalmos made the region most unsightly the patient asked for enucleation, which was done Sep. 26, 1916, and an artificial substitute gave an excellent result.

G. left Oct. 24, 1916, completely recovered.

**A case of post-traumatic enophthalmos; depression of the external orbital wall and of the inferior orbital margin.** (Case 45.)

J. R., Mechanic, aged twenty-one years, living at Poitiers, was cycling, March 16, 1912, when he collided with a carriage. R. was struck in the right orbital region by the mud-guard; the shock was so violent that it was broken and the patient thrown to the ground. At the hospital at Poitiers, where he was immediately taken, depression of the root of the nose and a smash of the external orbital margin were discovered. A large splinter of wood was taken from the temporal region, where it had lodged above the zygomatic arch; one of the nasal bones was eliminated through the nostril during an attack of hæmorrhage.

Suppuration was overcome with difficulty, and it was only after eighty eight days of treatment that cicatrisation could be obtained. R. then stated that he saw double, and as this constant diplopia rendered all work impossible he came to consult us on Oct. 17, 1912.

The patient bears numerous scars situated about the internal canthus of the right eye and on the lower eyelid, which is ectropionized; there is ptosis due to the enophthalmos; it is not accompanied by any lesion of the levator, which functions perfectly, as does also the superior rectus.

The eyeball is very markedly retracted, estimated at 5 mm. by comparison with the sound eye. This sinking in of the globe does not vary with the position of the head, and is not modified by effort. The eye, which is not supported by the external wall, has slipped outwards upon the orbital floor and is plainly deviated to the outer side and below. Hence the patient complains of crossed diplopia in every direction. The images are 20 cm. apart when looking ahead; this separation is much increased (80 cm.) when the candle is moved to the nasal side; it is slightly less on the temporal side. The patient complains

that in every direction the images are on a different level. The visual field is, however, normal; acuity = 1. Examination by oblique illumination shows that the cornea, quite transparent, has been entirely spared by the injury. The anterior chamber is of normal depth, the pupil presents nothing pathological, the iris reacts well to light and to accommodation. No trouble can be found in the transparent media, and the ophthalmoscope reveals nothing worthy of being put on record.

The left eye is quite untouched, the injuries not extending beyond the bridge of the nose; this eye is emmetropic and possesses acuity = 1.

In short, this was a traumatic enophthalmos due to depression of the external orbital wall, and perhaps also, in part, to the effects of prolonged suppuration of the tissues of the orbit.

By tenotomy of the four recti muscles the enophthalmos was considerably ameliorated.

### Symptoms and Diagnosis

In the cases in which enophthalmos is due to depression of the orbital walls there are always signs and traces, more or less old, of severe traumatism of the orbit. At the time of the accident there is abundant epistaxis and sub-conjunctival ecchymosis; profuse retrobulbar hæmorrhage may take place and bring about in the early stages an exophthalmos, which gives place later to enophthalmos.

During the whole of this early period the patient opens the eyes with difficulty, and it is only when the disappearance of palpebral swelling allows the ready separation of the eyelids that the more or less pronounced sinking in of the eyeball is noticed.

Usually it is about a fortnight before the patient opens his eyes; he habitually remarks in the first place that he sees double; this is the rule when visual acuity is good. It is often on account of the diplopia that the patient, till then in the hands of the general surgeon, seeks the advice of the ophthalmic specialist.

The latter immediately notices two principal symp-

toms, viz., ptosis and restriction in the ocular movements. The ptosis is generally due, not to paralysis of the levator, but to the fact that the upper eyelid has partly lost its natural support, which is the eye; it sinks in with it, and is lowered because it is sunk in, and in the same proportion.

In one of our cases, however, we noticed paralysis of the elevator, consecutive to traumatism of the supra-orbital region, which had directly implicated the levator palpebræ.

The eye is usually well fixed in its new position, and it is only in exceptional cases that intermittent enophthalmos and exophthalmos have been found; JEAN TERSON has reported three such cases.

The visual field is normal, the range of outlook restricted by the difficulty of excursion of the muscles; usually the media of the eye and the deep membranes are healthy. We shall not spend more time upon the symptomatology, which will be found in all the text-books, as well as in the thesis of DR. DAULNOY (Nancy, 1898–9), which is well supplied with references. We must limit ourselves to bringing forward here the symptoms presented by the cases we have reported above.

Our patient in Case 43 was a typical example of traumatic enophthalmos; the enophthalmic eye presented a slight opacity of the lens and papillary inflammatory troubles, but, the extrinsic musculature being intact, the diplopia complained of by the patient was the result of lowering of the eye by depression of the floor of the orbit.

In the same manner in Case 44 the radiogram shows a very clear depression of the inferior orbital wall; in this case, further, the eye, lessened in tension, was itself diminished in volume and had lost all acuity by reason of total detachment of the retina.

In Case 45, which was an example of grave traumatism worthy to be compared with traumatism of war, the enophthalmos, again due to bony depression, was very marked (5mm.); the subject had good visual acuity,

so good that he complained of a very tiresome diplopia some months after the injury. In his case a tenotomy of the four recti muscles, following DARIER'S procedure in similar cases, brought about great improvement.

Our other cases differ from the preceding in that trophic disorders were the cause of the enophthalmos. In one of the patients (Case 41) we had to do with a lesion of the frontal region due to an extra-orbital foreign body, which had perhaps caused a fracture of the orbit, irradiated to the apex, and which had implicated the motor and sensory nerves; the eye had preserved a good exterior appearance, but showed extensive detachment of the retina.

Finally, our Case 42 is a case of enophthalmos from nerve lesions and trophic troubles characterised by the following signs. The patient had a wound in the supra-orbital region; the visual acuity of the enophthalmic eye was 7/10, and there was paralysis of the superior rectus, the external rectus and the inferior oblique, entailing a very distressing diplopia. Probably the third and sixth nerves had been injured in the sphenoidal fissure, and at the same time the sympathetic filaments, emanating from the carotid plexus, had been torn at this level. The trophic disturbances were consecutive to this lesion. These two cases are types of true enophthalmos, as is also Case 40.

*Diagnosis.*—We do not think we need linger over the diagnosis of enophthalmos.

The appearance of the patient is usually characteristic and the diagnosis is made from a distance, at the first glance. In doubtful cases, at the onset of the affection, we may have recourse to the orthometers and ophthalmeters, recommended by HASNER, WAKNAM, ZEHENDER, COCCIUS, and MAKLAKOW; but it will be simpler and more practical to use for the same purpose the ophthalmometer of JAVAL. The eyes must be placed in a plane exactly parallel with the plane of the instrument, and, reflecting the "mires" of the instrument successively from each cornea, one notes how many millimetres it is necessary to advance the

instrument to focus it when examining the enophthalmic eye; this procedure is quite satisfactory and enables one to dispense with special apparatus.

We shall say nothing here concerning prognosis which is not familiar; the affection remains stationary when it is left to itself, and treatment yields but very mediocre results. We should here, however, mention the good results quoted by some writers, from electrical treatment by the continuous current; also tenotomy of the four recti muscles, advocated by DARIER.

This gave us a favourable result in one of our cases (Case 45).

## *CHAPTER V*

# FRACTURES OF THE ORBIT WITH DESTRUCTION OF THE EYEBALL

THE destruction of the eyeball may occur either with the presence of a foreign body or without the foreign body remaining in the orbit. The immediate disorders are the same; but in the second category of cases, the complications which result from the presence of the foreign body, come in to darken the picture.

Most frequently pieces of shell smashing in the external wall of the orbit, crushing the eye, and coming to rest near it or in the neighbouring cavities are the objects of interest in the cases of the second category. Bullets traverse the orbit and fracture it, but escape after having destroyed the eye and traversed the bony mass of the face.

We could report a large number of cases of this kind, but shall limit ourselves to the four following.

**Fracture of left orbit; rupture of eyeball; arterio-venous aneurism of the left internal carotid.** (Case 46.)

A., Sergeant, Infantry, was wounded April 14, 1915, by a rifle-bullet at M. Treated for ten days at Ch., he came to us April 27.

The rifle-bullet entered the left lateral part of the neck along the posterior border of the sterno-cleido-mastoid, three fingers' breadth below the inferior extremity of the mastoid process.

Following a course from below upwards and from behind forwards it came out at the level of the floor of the left orbit.

The left eyelid is totally destroyed; the aperture of exit is found almost in the inferior conjunctival cul-de-sac. The projectile has caused the rupture of the eyeball, which

is now reduced to a small shapeless stump, inflamed and painful.

The radiogram, whilst enabling us to determine the absence of a foreign body, shows a depression of the anterior portion of the floor and of the orbital margin. R. E. normal.

Enucleation of the left eye was performed April 30. During the next few days, A. drew our attention to a continuous buzzing in the ear, and left migraine. This

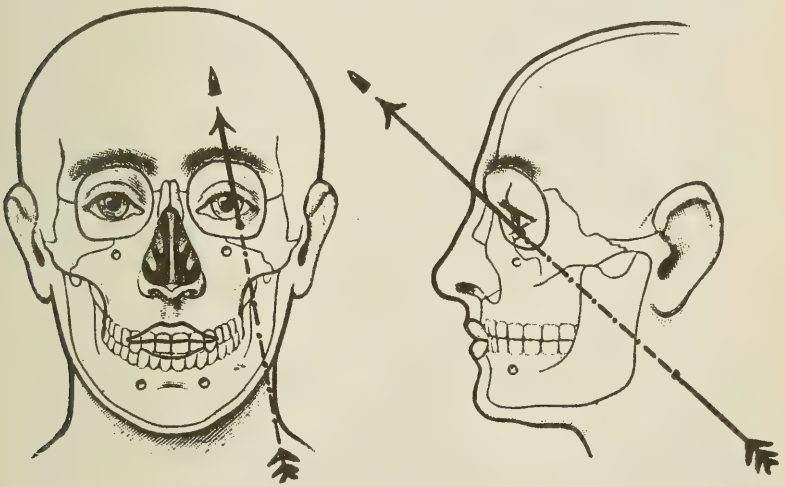


FIG. 50.

whistling, synchronous with the cardiac beat, was exasperating, causing atrocious headaches, and entirely preventing sleep. Extreme vaso-constriction of the face.

DR. LACOUTURE, called in consultation, concluded from his examination that there was an arterio-venous aneurism seated on the left internal carotid. Artery and jugular vein must have been injured by the bullet in its course.

May 5, 1915, ligature of the internal carotid. Post-operative progress most satisfactory; disappearance of all the symptoms; no complication has occurred since this intervention.

A blepharoplasty of the lower eyelid was done July 15, 1915, by means of a fronto-parietal flap. This operation allowed the patient to wear an artificial eye easily.

He left hospital June 17, 1915, completely recovered.

**Fracture of left orbit ; rupture of eyeball.** (Case 47.)

J. S., Infantry, rifle-bullet in the face, Aug. 28, 1914, at R. Made a prisoner, he was released June 25, 1915, and was admitted Aug. 4, the same year.

*Condition.*—The bullet penetrated the right ala of the nose; after having traversed the nasal fossæ from side to side it has fractured the left internal orbital wall a little above the lacrymal sac; continuing its course, it has ruptured the globe and emerged from the fronto-temporal region at the supero-external angle of the orbit.

At this point is to be seen a deep depression of the bone, the size of a crown-piece, produced by the fracture of the ascending process of the malar bone and the external process of the frontal bone. The cutaneous cicatrix extends to the external third of the eyebrow, which is much drawn downwards.

There is ptosis of the upper eyelid and symblepharon over the external third of the two eyelids; the lower eyelid is torn in the neighbourhood of the lacrymal sac, and is adherent below, in a vicious position.

The eyeball, entirely destroyed, was enucleated eight days after the injury.

The right eye is normal, V = 10/10.

Aug. 12, 1915, surgical intervention. In the first stage, the two eyelids were freed (section of the symblepharon); next, after freshening the inferior and internal palpebral border, it was drawn upwards, restoring the canthus. After dissection of the skin about the external orbital cicatrix, the very unsightly depression of the bone was filled up by means of adipose tissue taken from the left buttock. Sutures and dressings. Post-operative conditions excellent; the adipose graft took by first intention. In spite of this operation the conjunctival cavity remained atypical, very narrow, permitting, however, the use of an artificial eye.

S. left hospital Sep. 21, 1915.

**Fracture of the right orbit ; rupture of right eyeball ; traumatic choroido-retinitis and optic atrophy, L. E.** (Case 48.)

M. P., Infantry, wounded Jan. 14, 1916, by rifle-bullet. Taken to Ch. Jan. 15, he came to us Feb. 8, 1916.

*Condition.*—P. was struck by a rifle-bullet from a distance of about 150 metres. The projectile traversed the face from left to right, obliquely upwards and outwards; it penetrated at the union of the malar with the zygomatic arch, emerging by the supero-external angle of the right orbit, near the outer extremity of the eyebrow, traversing this cavity throughout its width, and causing an extensive fracture of the external wall, which can be felt depressed.

The right eye, ruptured and only existing in the form of débris, had been enucleated at once. The upper eyelid is destroyed in its external two-thirds; and surgical interference in two stages, Feb. 20 and Mar. 12, blepharoplasty by transplantation (pedicle) and Snellen's sutures, permitted the wearing of an artificial eye.

On the left side visual troubles appeared immediately after the injury. P. declares that on arrival at Ch. he found a very great diminution of visual acuity in that eye; it improved in the period immediately following, and since then it has remained stationary.

L. E. $V = 1/10$ good.

The globe is normal exteriorly. The pupillary reflexes are good; the transparent media clear.

In the macular region, especially marked below and to the inner side, there is atrophic and pigmented choroido-retinitis, secondary to a hæmorrhage of the membranes and causing a slight ascending atrophy of the optic nerve (concussion lesions). The disc is, in fact, decoloured, whitish, with contours somewhat pigmented.

Discharged July 7, 1916, in the same condition.

**Fracture of right orbit; rupture of eyeball.** (Case 49.)

E. S., Infantry, wounded Oct. 6, 1915, by grenade fragment. From Tarbes, he arrived Dec. 10, 1915.

*Condition.*—Cicatrix about 3 cm. long, direction vertical, in right superior orbital region. It starts from the anterior frontal region, 2 cm. above the eyebrow and two fingers' breadth from the root of the nose; the superior orbital margin is fractured at the junction of the inner third and the outer two-thirds. A deep notch of the underlying bony wall can be felt.

The upper eyelid is divided and in a condition of

cicatricial ectropion; the palpebral borders are adherent to the depressed bone.

The ruptured eyeball was enucleated two days after the injury. The left eye is normal, V = 10/10.

Jan. 10, 1916, restoration of the upper eyelid was proceeded with. The cicatricial tissue was undermined, and after refreshing the two ciliary borders the palpebral portions were sewn together. Snellen's sutures were used to deepen the superior conjunctival cul-de-sac. An artificial eye was given.

S. left hospital Feb. 6, 1916, completely recovered.

These four cases all present remarkable peculiarities.

The first concerns a patient who, in addition to his serious orbital lesion, had an arterio-venous aneurism of the internal carotid and the jugular; this aneurism was cured by ligature of the internal carotid performed by Dr. Lacouture; it was afterwards possible, by means of a blepharoplasty, to restore the eyelids in such a manner as to permit the wearing of an artificial eye.

The second case furnished us with the opportunity for practising with success our first adipose graft, permitting us to repair the large loss of substance resulting from the destruction by a bullet of the external process of the frontal and of the malar bone.

The third is a subject in whom, besides the rupture of the right eye, we noted in the left eye macular concussion lesions already fully described (see p. 896).

The fourth case is remarkable for the presence of an important fracture of the whole of the superior margin of the orbit, coupled with an extensive destruction of the upper eyelid. A Snellen's suture above and an appropriate blepharoplasty allowed us to place this subject under conditions for an æsthetic prothesis.

In all these cases, as well as in those in which the eye has been struck by a bullet, the organ was destroyed in such a manner that only débris remained, and it is impossible to give an account of the mechanism which has been responsible for the rupture.

Shrapnel balls or shell fragments reduce the eye to the condition of a stump, but do not like bullets tear it in pieces; one finds still in the orbit a more or less painful stump, with a foreign body in its vicinity. The injury to the eyeball is not less serious; on the contrary, this shrivelled and torn globe retains in its interior the inflamed uveal tract, which is brought in contact with the infected orbital cavity by means of the ruptures in the sclerotic, and thus serious irritation may result, implicating the other eye.

When the eye has been torn to pieces by a ball, or opened by the explosion of a grenade, usually the uveal tract begins to suppurate, and suppuration is the enemy, the antagonist, of sympathetic ophthalmia; the choroid is eliminated and very soon nothing remains of the contents of the burst ocular envelope. On the other hand, when there has been attrition and rupture of the eye by a shell-fragment the withered eye shrivels up, keeping in its interior inflamed uveal tissue; the painful stump remains, with all its danger. This is demonstrated by the following cases.

**Wound of the left temporo-orbital region; fracture of the external wall of the orbit; rupture of the eyeball; persistence of foreign body in the orbit.** (Case 50.)

C. D. Infantry, wounded in Champagne by shell fragments; after twelve days reached Bordeaux, April 12, 1916.

*Condition.*—On his arrival, there was a large wound, extending from about 2 cms. from the meatus of the left ear to the external third of the left lower eyelid. There was a comminuted fracture of the zygomatic process and of the malar bone.

The inferior orbital margin is also the seat of a notch caused by the projectile.

The left lower eyelid is pulled down on its outer side. The eyeball persists, at the bottom of the orbital cavity, in the form of a small inflamed and painful stump.

Radiography shows the existence of a large shell fragment lodged in the orbit behind the stump (Fig. 51).

May 18, 1916, enucleation of the eyeball and extraction of the foreign body. We then proceeded to restore the

outer third of the destroyed lower eyelid by transplantation of a flap taken from the external orbital region.

Cicatrisation by first intention.

R. E. intact. V = 10/10.

The prothesis has been specially moulded; after progressive dilatation, the wearing of an artificial eye of almost normal size has been tolerated.

FIG. 51.

**Fracture of the right orbit; rupture of the eyeball; shrapnel ball at the apex of the orbit.** (Case 51.)

A. C., Sergeant, Infantry, wounded at A., Aug. 24, 1914. From Troyes, viâ Casteljaloux, he arrived at Bordeaux Oct. 20, 1914.

*Condition.*—In the external orbital region is seen a depressed cicatrix, with starred margins, probably the orifice of entry of the projectile. Beneath can be felt the fractured ascending process of the malar bone.

Two months after the injury there was still voluminous chemosis below, evidence of an intra-orbital effusion of blood, absorbed, with inflammatory sequelæ.

The eyeball is reduced to a small stump covered by conjunctiva, clearly felt on palpation.

Since the injury C. has experienced sharp pains in the right supra-orbital region.

Radiography shows the presence of a shrapnel ball, lodged in the right orbit, towards the apex (Fig. 52).

Oct. 28, 1914, we proceeded to enucleate the stump. Orbital exploration allowed us to mark the exact location of the projectile, which was extracted by the gouge with difficulty.

Post-operative progress excellent.

C. left hospital Nov. 12, after the fitting of an artificial eye. The left eye was normal.

L. E., with + 0·50 D sph., V = 9/10.

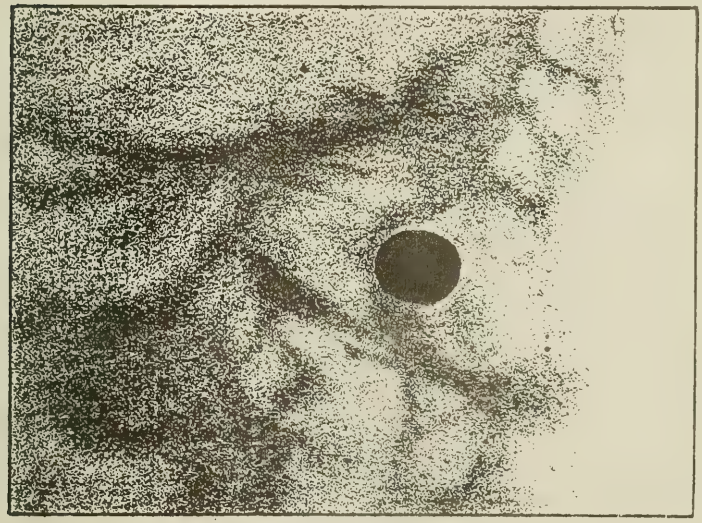


Fig. 52.

Still more curious is the following case, in which we found a foreign body by the side of the optic nerve, irritating it to the point of determining, not attenuated sympathetic phenomena, but a true ophthalmia.

**Foreign body irritating the optic nerve ; sympathetic ophthalmia.** (Case 52.)

A. T., Infantry, wounded Oct. 11, 1915, at P. Admitted Oct. 24 of the same year.

*Symptoms on Admission.*—T. had a perforating wound of the eyeball from a shell wound. The eye was in a condition of complete panophthalmitis at the time of our first examination. The left eye was normal, V = 10/10. Evisceration of the globe was performed Oct. 28, 1915, with all possible care to leave no trace of the uveal tract in the scleral envelope.

Nov. 7. T. complained, for the first time, of a sensation of mistiness and diminution of vision in his left eye. Ophthalmoscopic examination revealed the existence of a well-marked optic neuritis; acuity then equalled 1/10.

The next day enucleation of the stump on the right side was performed. Dissection of this stump showed that a tiny portion of shell was in the substance of the sclerotic, *in contact with the optic nerve.* Intensive mercurial treatment was commenced (intravenous injection of cyanide, friction with mercurial ointment, counter-irritation atropine).

The neuritis improved slowly and progressively, so that on May 30, 1916, the visual acuity, with + 1·25 D sph. again equalled 10/10; the disc presented a normal aspect, its scleral borders quite clear.

He was discharged May 27, 1916, completely recovered.

We now arrive at a variety of fractures of the orbit of the greatest interest, those which are accompanied by destruction of the eyeball with implication of the neighbouring cavities.

## Fractures Implicating the Neighbouring Cavities

We shall group the cases of this kind into three series, according as the orbital fractures involve: (*a*) the maxillary antrum; (*b*) the frontal sinus; (*c*) the cerebral cavity.

It is evident that these three varieties present different degrees of gravity and characteristic symptoms, but they have everything in common from the ætiological point of view. It is almost always pieces of shell, fragments of grenades, rarely shrapnel balls, very exceptionally bullets, which bring about the great facial and cranial derangements. The bullet is a narrow

projectile, involving disorders at a distance by vibration or oscillation of the tissues. The pieces of shell shake the neighbouring regions less, but they break the bones, drive in the walls, and cause the orbital cavity to communicate freely with the cavities which surround it. By way of a specimen we reproduce here

Fig. 53.—Smash of the orbital region by a large piece of shell.

a photograph (Fig. 53) portraying the lesions produced in such a case in the orbital region; and two radiograms (Figs. 54 and 55), which represent two good examples of fracture with loss of substance.

Of these two radiograms, one (Fig. 54) refers to a subject in whom the loss of substance has been repaired by a cartilaginous graft; it is drawn from a very correct proof. The other (Fig. 55) refers to Case 64 (p. 964).

One can see plainly there the crushing in of the external wall of the orbit. We give these two types of fracture by way of example; we have many others in our collection.

The attrition which results from such traumatism is quickly followed by suppuration, and thus is developed sinusitis, interminable if not remedied, or

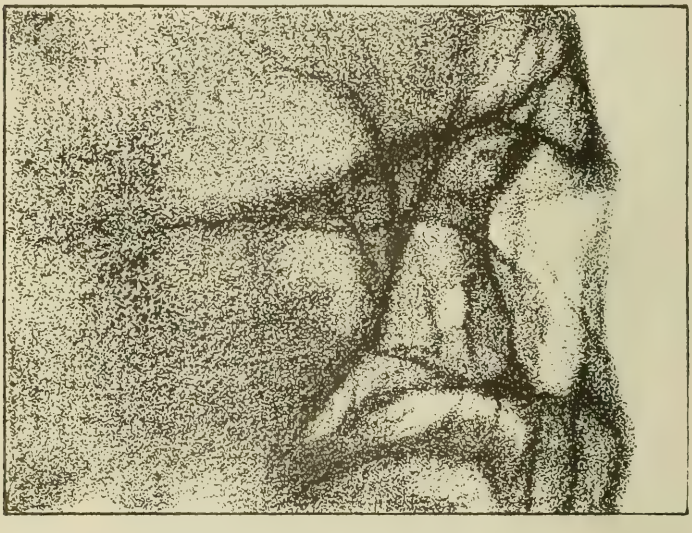


Fig. 54.—Fracture and loss of substance of the left external orbital region.

rapidly fatal cranial disorders, if efficacious interference is not quickly brought to bear.

It is these cases of fracture of the orbit with opening of the sinus and destruction of the orbital margins which need the plastic operations with grafts of which we shall speak later.

### (*a*) Maxillary Antrum

We could multiply cases here, but as in our other groups we shall be content with choosing a few out of our collection.

**Fracture of the floor of the left orbit; crushing of eyeball.** (Case 53.)

L. O., Sergeant, Infantry, wounded Aug. 28, 1914, at B., by shell. No loss of consciousness. Dressed the same

Fig. 55.—Fracture of the supero-external region of the left orbit.

evening, he went first to Libourne, thence to Bordeaux, admitted Oct. 7.

*Examination.*—There is an extensive wound of the left infero-external orbital region; the divided lower eyelid is wanting in its external two-thirds; in this region the

integuments are absent and leave the maxilla bare; its vault and anterior wall are smashed in. The outer part of the upper eyelid is equally destroyed as far as the outer extremity of the eyebrow, and is adherent to the underlying bone.

The patient discharged large quantities of pus due to well-marked sinusitis, from the wound and from the nose, and on Sep. 13 expectorated a large splinter. which came from the anterior wall of the sinus.

The left eyeball presents a rupture of the sclerotic at its lower part, on the side of the orbital fracture. Reduced

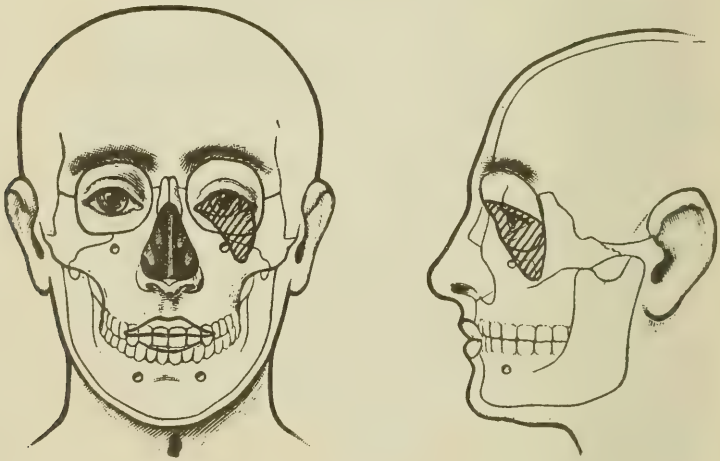


Fig. 56.

to the condition of a stump, its enucleation was judged to be necessary, and this was done Oct. 14.

Upon the radiogram we see very clearly the depression of the anterior wall of the antrum and the crushing in of the floor of the orbit. There is a small foreign body in the sinus. Some small bone fragments are situated near the hole in the maxilla; one, larger, is in the pharyngeal region, explaining the difficulty in chewing and swallowing.

Oct. 14, besides enucleation, we proceeded to repair the anterior wall of the antrum and the eyelids; the drainage of the antrum was afterwards effected, after cleaning up with a curette.

In the second stage, blepharoplasty of the two eyelids,

by transplantation with a pedicle. The result of the operations was most satisfactory.

**Fracture of the left orbit and of the left maxillary sinus ; rupture of the left eyeball.** (Case 54.)

E. C., Infantry, wounded Feb. 25, 1916, by a grenade which burst one metre from him. He was immediately trephined in a field hospital. He stayed twelve days at C., and reached us March 27, 1916.

*Examination.*—The projectile had penetrated the left maxillary antrum, and after having traversed the left orbit from side to side emerged from the fronto-parietal region of the same side.

There is a large wound of the fronto-parietal region, in a fair way to cicatrisation.

At the anterior portion of the antrum is seen an irregular wound (aperture of entry of the shell fragment), which is freely suppurating. The ruptured left eye remains in the form of a small stump at the bottom of the conjunctival cavity.

Radiography shows a small projectile situated in the maxillary sinus; also two or three splinters, the cause of the prolonged suppuration of the wound. The inferior orbital margin and the floor of the orbit have both been fractured.

In the frontal bone is an extensive loss of bone substance, resulting from the trephining. A small shell fragment remains at the edge of the bony orifice.

April 7, the stump was enucleated; next, the maxillary antrum was carefully curetted; this permitted of the extraction of the shell fragment, the splinters mentioned above, and some fragments of calcareous stone.

June 8, 1916, maxillary fistula was cicatrised.

The orbital cavity, although reduced in volume by the lacerations of the conjunctival mucous membrane, allows the wearing of an artificial eye.

R. E. intact. V = 10/10.

**Fracture of right orbit and frontal sinus ; destruction of the eyelids and of the right eyeball ; voluminous foreign body in the left maxillary antrum.** (Case 55.)

E. M., Infantry, wounded Feb. 15, at M. Immediate

loss of consciousness; he was transported to Ch., where the right eye, reduced to a pulp, was enucleated. Admitted Feb. 25.

*Examination.*—This soldier has been struck in the right orbito-ocular region by several portions of shell, which have caused the following injuries—

(1) Fracture of the frontal bone, and wide opening up of the frontal sinus, which was freely suppurating at the time of our examination.

(2) Fracture of the superior orbital margin at its outer end. The right eyelid has been torn and partly destroyed at this point.

(3) Laceration of the lower eyelid, which, owing to œdema, assumes the shape of an inflated bag.

(4) Rupture of the right eyeball (enucleated), and fracture of the floor of the orbit, easily felt on palpation through the conjunctival sac.

The left eye is intact; its visual acuity equals 10/10. Radiography shows the presence, (1) of a small shell fragment in the right orbit; (2) of another somewhat larger in the left nasal cavity; (3) of a third, very large, measuring 2 cm. long by 1 broad, with irregular contour, lodged in the left maxillary sinus.

Penetrating at the level of the right orbit it has therefore crossed the nasal fossæ from side to side and fractured the right antrum.

March 1. After opening the anterior surface of the left sinus the projectile was extracted. Drainage; sutures. Recovery was rapidly obtained.

March 25. Blepharoplasty by the aid of a cutaneous flap from the frontal region, which allowed restoration of the outer part of the upper eyelid. Dissection of the injured tissues of the lower eyelid and their suture in good position.

Placing of Snellen's sutures to restore the inferior conjunctival cul-de-sac.

After dilatation and taking a cast of the conjunctival cavity, an artificial eye could be fitted; discharge, Aug. 12, 1916.

The wound of the frontal sinus had cicatrised without its being necessary to proceed to an operation for restoration.

**Fracture of the internal wall of the left orbit; destruction of the nasal wall and of the antrum; rupture of eyeball; burying of the eye in the antrum.** (Case 56.)

A. G., Infantry, wounded Aug. 24, 1915, by shell fragments. From Ch. he went to Arcachon, Sep. 5, thence to Bordeaux, Sep. 8.

*Examination.*—A large piece of shell penetrated at the level of the supero-internal angle of the left orbit, and came to rest at the anterior surface of the median portion of the left maxilla.

In its course it produced the following injuries—

(1) Laceration of the inner canthus.

(2) Fracture of the inferior orbital margin and of the floor of the orbit, entailing the almost complete destruction of the lower eyelid.

(3) Rupture of the left eyeball, reduced to the condition of a shapeless stump at the bottom of the conjunctival sac.

(4) Fracture of the maxilla, of the os unguis and the nasal bone on the left side, producing an irregular cavity formed by the widely open maxillary sinus and nasal fossæ. These two cavities communicate by a wide aperture.

The wound has been suppurating for a long time, and it has been necessary to wait two months before being able to attempt an operation for restoration.

Dec. 5, 1915, an attempt was made to close this opening, after dissecting up the cutaneous layers on the margins of the opening into the antrum and nose. Blepharorrhaphy and superficial sutures. Subsequently the sutures gave way and the cicatrisation of the flaps took place in bad position.

Three weeks later, blepharoplasty by transplantation of a flap with pedicle taken from the left fronto-parietal region. The two external thirds of the graft took by first intention, but the internal third, not sustained by a vascular base, necrosed after a short time, leaving the orifice open, but much smaller than before.

G. was sent on three months' convalescent leave before attempting a third operation; it was in the course of this third and last operation, the result of which was satisfactory, that we found the débris of the eye in the interior of the cavity of the antrum.

The right eye was normal. $V = 1$.

**Fracture of the floor of the right orbit; cicatricial ectropion; traumatic choroido-retinitis; large piece of shell in the antrum.** (Case 57.)

A. L., Infantry, wounded Jan. 9, 1916, at M.; from Ch. he arrived Feb. 4, 1916.

*Condition.*—The shell fragment has penetrated a centimetre below the right inferior orbital margin, in its median part; at its entry we note upon the anterior surface of the antrum a depressed, suppurating, cicatrix; a probe introduced into the orifice leads to the maxillary sinus itself, in a direction from before backwards and from below upwards, to beneath the floor of the orbit.

Radiography shows this fracture of the anterior wall of the sinus, and, in addition, a fracture of the orbital floor. The fragment is found in the cavity of the antrum at its posterior part, near the orbit.

The right eye is the seat of extensive disorder; patches of peripapillary and macular choroido-retinitis (concussion lesions), numerous choroidal hæmorrhages below, on the side of the orbital fracture (contact lesions).

Acuity barely 1/100.

The lower eyelid has healed in a bad position; cicatricial ectropion produced by the retraction of the palpebral tissue injured at the site of the wound.

At the first operation, Feb. 19, 1916, the wall of the antrum was widely laid open and a flood of pus escaped. The foreign body was easily extracted by means of a gouge, as well as some bone splinters coming from the floor of the orbit. Drainage and suture. The wound has been a long time healing by reason of the sinusitis.

When healed, blepharoplasty by transplantation of a pedunculated flap, for restoration of the lower eyelid.

Rapid healing by first intention.

Discharge July 3, 1916.

The reading of these five case-reports gives a clear idea of the diversity of the injuries to the maxillary antrum. In Case 53 all the infero-external orbital region was destroyed, the vault and the anterior wall of the maxillary sinus were crushed in; the anterior wall of the sinus has been eliminated as a splinter. In

Cases 54 and 55 the anterior wall of the sinus has also been destroyed by a fragment of grenade, and its fragments have fallen in splinters into the sinus itself. Case-report 55 treats of a fracture of the maxillary sinus by a large piece of shell which was extracted from the cavity. The fourth case (56) is still more

FIG. 57.

interesting in the sense that, besides the large opening allowing the maxillary sinus to communicate with the nasal fossæ, we found, at the time of one of the reparatory operations which have been done, the left eye crushed down into the sinus. Finally, in the fifth report (Case 57), given here as a specimen, we again found a piece of shell (Fig. 57) in the posterior part of the cavity of the sinus, against the floor of the orbit.

### (*b*) Frontal Sinus

The frontal sinus is sometimes attacked alone by the instruments of violence which fracture the orbital walls; here, most frequently, we have to do with a bullet whose course from below upwards, or from above downwards, meets the frontal sinus and traverses it. Out of the three cases we give of lesions of the frontal sinus, two are concerned with bullet wounds, the third with traumatism by shell fragment.

**Fracture of the supero-internal orbital wall; opening of the left frontal sinus.** (Case 58.)

L. H., Infantry, wounded Sep. 25, 1915, at Saint-H., by a rifle bullet at the level of the inner extremity of the left eyebrow. Transported to Saint-H., he reached our service Oct. 5, complaining of diplopia.

*Condition.*—The projectile has entered at the supero-internal angle of the left orbit and emerged at the internal third of the right eyebrow, at a centimetre distance from the latter.

In its course it has fractured the left frontal sinus, which at the time of our examination is widely open.

Palpation, very painful, reveals the existence of a notch of the orbital margin, at the point of penetration of the bullet. In addition there is a depressed cicatrix adherent to the deep parts.

Radiography confirms the fracture of the left frontal sinus. The left eyeball is normal; no lesion of the refringent media or deep membranes to be found.

Visual acuity of the left eye equals 10/10.

H. complains of a very distressing diplopia following the traumatism. Study of the false image reveals paralysis of the left superior oblique muscle. It is probable that the projectile has divided the pulley of the muscle situated at the fractured spot.

The frontal wound had cicatrised spontaneously, and H. went on convalescent leave with persistent diplopia and almost constant violent headaches.

**Fracture of the facial bones by a bullet ; fracture of the frontal sinus and of the ethmoid ; adipose graft.** (Case 59.)

E. H., Infantry, was wounded Oct. 17, 1915, at A. Sent to Sainte-Menehould, afterwards to Vichy, where ablation of splinters and extraction of the ethmoid were effected.

*Condition.*—On arrival July 7, 1915, it was found that the bullet had penetrated the root of the nose, passed along the internal wall of the right orbit, without fracturing it, traversed the superior maxilla and the roof of the

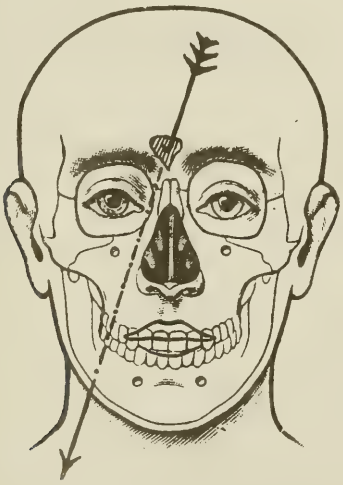


Fig. 58.

mouth, coming to rest in the lateral part of the neck. In its course it had broken into the frontal sinus and the ethmoid.

The eyes are intact, and their visual acuity is normal.

The sole lesion evident is obstruction of the right lacrymal passages, probably due to a fracture of the nasal canal.

The bullet was extracted Aug. 9, 1915, by the aid of the classic incision used for ligature of the carotid; it was found near the superior border of the thyroid cartilage, under the anterior border of the sterno-cleido-mastoid.

Post-operative progress normal.

H. left hospital in Sep. 1915, with persistence of lacrymation on the right side.

On his return from convalescent leave we proceeded to

resect the vicious cicatrix at the root of the nose. After splitting the cutaneous covering the cavity was filled in by the aid of fatty tissue taken from the right buttock.

Union by first intention.

The adipose graft gave an excellent result from the æsthetic point of view.

**Fracture of the left fronto-orbital region involving the frontal sinus ; hæmorrhage into the vitreous body ; adipose graft.** (Case 60.)

E. B., Infantry, wounded Sep. 25, 1915, at B., by a shell ; viâ Perigueux to Bordeaux, where he arrived Nov. 9, 1915.

*Condition.*- The piece of shell had produced a wound seven centimetres long, beginning at the left upper eyelid, implicating the end of the eyelid and the frontal sinus, which was laid widely open. The wound had become infected, and suppuration has been fairly abundant.

On the patient's arrival the wound of the sinus had a fistulous aspect, some drops of purulent fluid welling up.

The upper eyelid is divided at the site of the internal third. The eyeball, severely contused, is of normal tension, but in the vitreous body numerous clots float (traumatic hæmorrhage) ; visual acuity equals 4/10.

Radiography shows a large loss of bony substance in the region of the frontal bone, its base in the form of a crescent with the concavity posterior.

During his stay in hospital there was elimination of several bone splinters from the fistulous opening into the sinus ; slow healing.

When suppuration had ceased we proceeded to effect palpebral restoration by suture of the two divided portions. Result excellent. The sinus is filling up little by little, giving rise to a depressed cicatrix. May 25, 1916, adipose graft. The skin, very adherent to the deep parts, required most delicate dissection.

The graft, taken from the left buttock, preserved perfect vitality, and healing took place by first intention.

B. left in June 1916. The acuity of the left eye was always 4/10.

Case 58 is a type of fracture localised as it were by

the sinus itself; the sole region of the orbit concerned is that which limits the sinus at its internal and inferior aspect, and the only visual disorder ascertained was impotence of the superior oblique, due to the destruction of the pulley of this muscle. Case 59 is in much the same condition; the bullet, as shown in Fig. 58, has penetrated at the root of the nose and passed along the internal wall of the orbit without fracture, traversed the maxilla and the floor of the mouth, coming to rest in the carotid region whence it was extracted. In this case, in short, we were dealing with a fracture involving the orbit to the minimum, and traversing the face from top to bottom while causing as little mischief as possible.

Shell fragments affect the parts injured more severely; in Case 60 we have to do with a shell fragment which has caused a wound seven centimetres long in the region of the frontal sinus, which was widely laid open; the whole anterior wall of the sinus was eliminated, and a deep cupuliform cicatrix produced, which was satisfactorily filled up by an adipose graft.

### (*c*) Cranial Cavities

The cases in which the cranial cavity has been opened ought evidently to be considered as cases of the gravest, *quoad vitam*, with which the ophthalmologist can have to deal. At the same time it would be an error to believe, even when the cerebral substance is largely laid bare and a portion of this substance has been sacrificed, that the prognosis is necessarily fatal. We shall cite cases subsequently, which demonstrate the relative benignity of such disorders. In the literature (brought under contribution as little as possible in this book), we find similar cases discussed. We shall content ourselves with making particular mention of those cases which have been recorded by our colleagues, the heads of the ophthalmic centres, in their monthly reports; the cases observed at the clinic of the Quinze-Vingts by Valude, Chevallereau,

Chaillons and Pompeani merit particular attention (Report of January, 1915).

In one case, a rifle bullet, penetrating the intersuperciliary region, traversed the anterior lobes of the brain, the left frontal sinus, the orbit and maxillary sinus, etc. The patient lost two tablespoonfuls of cerebral matter, but remained in excellent general condition. Another patient, wounded by a piece of shell in the median and superior portion of the frontal bone, presented a large opening communicating with the orbital cavity and quite near the frontal lobes, with pulsations synchronous with the cardiac beat; these two patients recovered. A third case, wounded in the same manner, died. We have cases to set beside these to the number of four, and, in one only, was the termination unfortunate. We report them here, as briefly as possible, but in all their essential details, on account of the gravity of the disorders concerned.

We are of opinion that we should distinguish in the cranial trouble consecutive to orbital fractures, or rather concomitant with them, two orders or classes of cases: those in which the phenomena observed are slight, temporary, without important symptoms; and those in which the aspect of the affection has been disturbing from the outset, by reason of inflammatory manifestations.

We publish these cases according to their increasing gravity, terminating by the only fatal case observed in our clinic.

**Fracture of the left orbit; retrobulbar neuritis, L. E.**
(Case 61.)

H. C., Infantry, wounded May 19, 1915, at N. V. by a shell. Trephined the same day, he was afterwards sent to Rennes, Saintes, and Bordeaux, where he came under our observation.

*Condition.*—There is an injury of the left fronto-parietal region and the orbito-ocular region. At two centimetres from the external angle of the orbit there is a depression

in which one can bury the tip of the index finger. The external wall of the orbit is therefore fractured.

The patient complains since the injury of enfeeblement of the left eye, the acuity of which equals no more than 1/10, verified by the tests in use to check malingering.

Ophthalmoscopic examination reveals no lesion. The disc and the vessels are normal. The visual field is slightly contracted, but there is no scotoma. We are probably

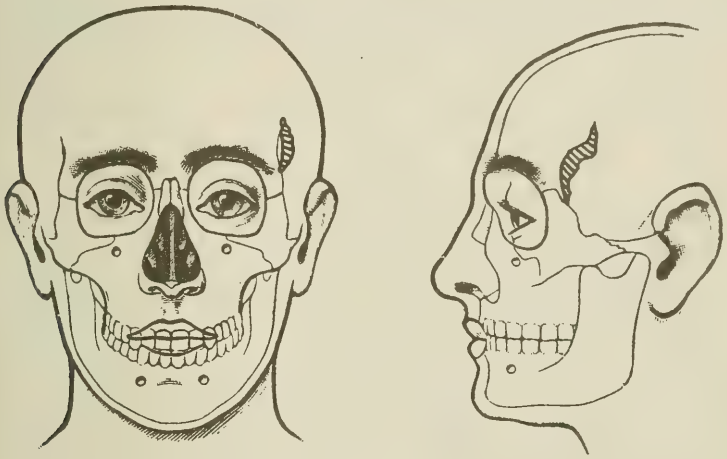


Fig. 59.

dealing with a retrobulbar neuritis, consecutive to the traumatism.

In addition there is paralysis of the external rectus muscle of the eye, causing homonymous diplopia, which the patient corrects by inclining his head towards the left shoulder.

C., besides his orbito-ocular troubles, has a fracture of the mandible.

He also presents some derangement of the nervous system. When upright, he is seized with vertigo, and is obliged to lean on a stick to support himself with his hands. Lying down, the vertigo is equally frequent, but much less violent.

Complete deafness on the left side.

Cutaneous anæthesia of the left part of the face is noted. Disappearance of the achillean and plantar reflexes. C.

complains of headaches and violent buzzing noises. His condition is the same at the time these notes are written, but the visual acuity equals 1/3.

**Fracture of the left orbital vault by shell fragment ; perforation of the globe ; total detachment of the retina.** (Case 62.)

J. N., Infantry, wounded Sep. 25, 1916, at S. by a shell; from Chalons Oct. 4, at Bordeaux Oct. 7.

He presents an injury of the left fronto-parietal region, at the level of the descending branch of the frontal. The

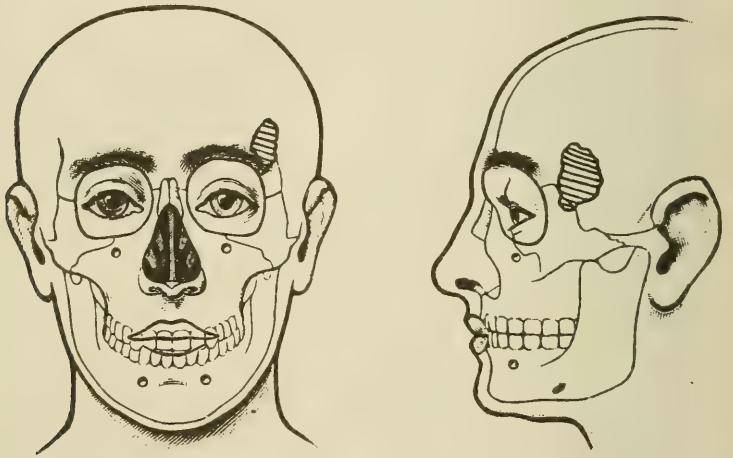


FIG. 60.

fragment has penetrated here into the cranial cavity, after having fractured the frontal portion of the orbital vault.

By the orifice of entry we note an extensive loss of bone substance of the size of a crown-piece, produced by the fracture and by the trephining done at S., Sep. 26, 1915, and a second time at Bordeaux, Oct. 21, 1915 (extraction of fragments and splinters and reduction of a cerebral hernia).

The eyeball has been perforated at its posterior part and is now reduced to the condition of a stump, not painful spontaneously or on pressure (traumatic irido-choroiditis and total detachment of the retina). The right eye is intact.

R. E. V = 10/10.
L. E. V = 0.

Radiography shows the presence in the neighbourhood of the wound of two projectiles (shell fragments) which have not been extracted.

A fortnight before the second trephining, N. was seized with complete aphasia, which disappeared after surgical interference and has not recurred since.

No disorder of the nervous system, central or peripheral.

His general condition has been most satisfactory, but on March 12, 1916, without cause, the patient had a sudden loss of consciousness, which lasted about half an hour.

**Fracture of the apex of the left orbit ; bilateral papillary stasis ; " mal comitial " (epilepsy).** (Case 63.)

F. B., Chasseur à pied, wounded Jan. 19, 1915, at A., by shell. The fragment has penetrated at the level of the left temporo-maxillary articulation. The patient remained eight days unconscious and delirious. B. was operated upon at Blois, July 3. His case-sheet bears the following note : " Extraction of a large piece of shell, lodged behind the left zygomatic process and the inferior maxilla. When the fragment was removed cerebral matter was seen in the wound. By radioscopy, a probe introduced into the breach passes into the cranium at the level of the temporal convolutions, passing behind the eyeball and through the fractured wing of the sphenoid. No operation."

Since his admission, July 18, 1915, B. has had two or three relapses, crises of delirium, preceded by headaches and a sensory aura (sensation of a bad smell). The crises are not accompanied by loss of consciousness, but by absolute amnesia, pallor of the face and difficulties of speech.

The patient was examined with reference to these attacks in the neurological clinic, where this diagnosis was made : " epileptiform attacks, probably of commissural origin consecutive to traumatism." No disturbance of the peripheral nervous system. The orifice of entry of the projectile is found a little in front of the left temporo-maxillary articulation. Radiography does not allow us definitely to assert the presence of a visible fracture, and there is no trace of a foreign body.

There is no trouble with the extrinsic musculature of the two eyes. On the left one notices a breach in the

iris similar to that produced by an iridectomy, but B. affirms that he has never been operated upon.

The transparent media are normal. The papillæ present *the classic type of choked disc*, and this œdema is more marked on the left than on the right.

R. E., with — 2·50 D sph., V = 1/10.
L. E., with — 1 D sph., V = 2/10.

In consideration of the meningeal irritation and the antecedents surgical interference was withheld, and B. went on convalescent leave Jan. 10, 1916.

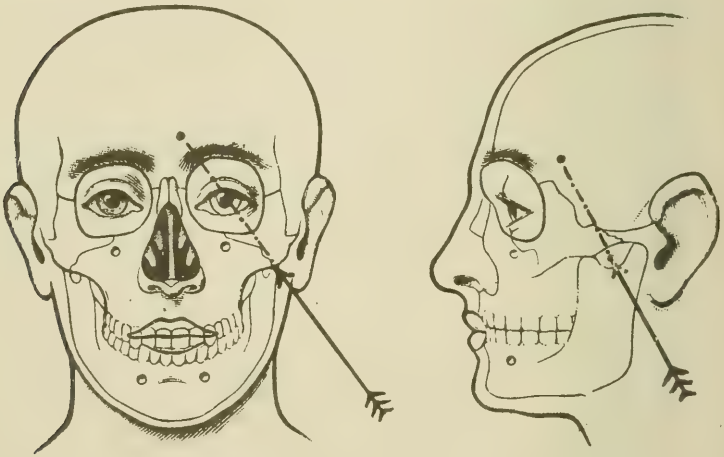


Fig. 61.

**Fracture of the left orbital region in the fronto-temporal part ; fracture of the orbital vault ; loss of cerebral substance ; contusion of the globe ; hæmorrhage into the vitreous.** (Case 64.)

B. V., Infantry, wounded June 27, 1916, at M. by shell, in the left fronto-temporal region. The field hospital case-sheet bears the following notes : " A large shell fragment has penetrated the left fronto-temporal region at two centimetres above the supero-external angle of the left orbit, severely fracturing the orbital vault, opening direct communication with the encephalon (Fig. 55, p. 949). Next, it has divided the left optic nerve, seriously contused the eye-

ball, and, after having traversed the nasal fossæ, has lodged on the anterior surface of the right maxillary sinus, whence it was extracted June 28, 1916. At the moment of the injury there was an abundant escape of cerebral matter.

In the following days the temperature rose; enormous exophthalmos appeared, due probably to inflammatory reaction of the intra-orbital tissues. The globe was enucleated July 2, 1916, and the vitreous was found to be full of blood-clot. Then was remarked a very extensive loss of bone substance from the vault and the supero-external wall of the orbit, making a communication between it and the cranial cavity on the one side, and the exterior on the other.

Rapid improvement in the condition of the patient, whom we saw Oct. 14. At this date there was complete cicatrisation of the left fronto-temporal fracture, where there was the sensation of cerebral pulsation.

An artificial eye was fitted.

There is no derangement of the central or peripheral nervous system.

R. E. normal; with + 1 D cyl., axis 165°, V = 10/10.

**Fracture of the right orbit by grenade ; rupture of the left eyeball ; cerebral abscess, recovery.** (Case 65.)

J. B., Infantry, wounded Jan. 11, 1916. Admitted Feb. 25, in a state of marked prostration; torpor, low temperature; slight Kernig's sign, no stiffness of the neck, pulse very slow (46). Two pieces of grenade had penetrated the lower portion of the right orbit, traversed the eyeball, which is reduced to its scleral envelope, perforated the orbital vault, and come to rest in the cerebral substance in the right superior parietal region.

Radiography enables us to locate the two projectiles, and at the same time to ascertain the loss of bone substance of the orbit. The general symptoms, added to these clinical reports, suggest a sub-dural cerebral abscess in course of development.

Feb. 20, 1916, enucleation of the stump was performed; then, by an incision at the level of the right eyebrow, the orbital periosteum was detached by means of a gouge. The whole roof of the orbit was thus laid bare, and we

noted the presence of two bone apertures in the upper part, one of which was the size of a half-franc piece.

Fig. 62.

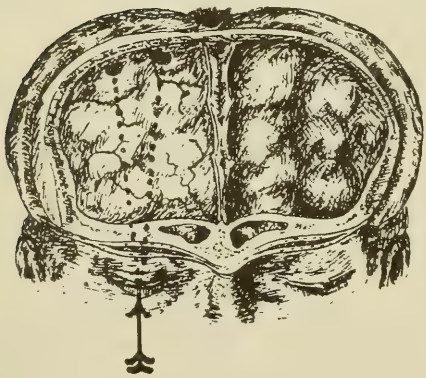


Fig. 63.

A splinter, 1 cm. long by 4 mm. wide, was extracted, and the orifice cleaned by means of a blunt curette. A large quantity of purulent liquid welled up from the sub-dural region. The parts were washed with hydrogen peroxide lotion; by removal of the external orbital process, dependent drainage was arranged. Sutures.

Post-operative conditions uneventful. The temperature, after having risen to 38·6° C. (101·5° Fahr.), quickly returned to the normal, and the pulse to 72.

May 7, 1916, B. had completely recovered, and his general condition was most satisfactory. The headaches had disappeared, and the patient attended to the occupations of daily life without complaining of his injury.

May 23, a palpebral fibrous band was incised; the wearing of an artificial eye then became practicable.

**Smash of the orbital vault; rupture of eyeball; intra-orbital meningo-encephalocele.** (Case 66.)

C. R., Infantry, wounded in A., Feb. 1, 1915, by rifle bullet. Immediate loss of consciousness. Treated in field ambulance. He there underwent an operation, upon the nature of which we have been unable to obtain information.

Admitted April 29, 1915.

*Condition.*—The projectile had penetrated in the right frontal region, at about 3 cm. from the supero-external angle of the right orbit. After having traversed the orbital cavity from side to side it emerged at the root of the nose.

Palpation of the injured region does not enable any bony depression to be detected, except at the point of penetration of the bullet. No cerebral pulsation.

The eyelids are intimately adherent to each other over their whole extent (total symblepharon). On palpation through this palpebral veil there is the sensation of a resistant mass, not fluctuating; and—we insist on this detail—no pulsation synchronous with the cardiac contractions was perceived; we thought it was probably the right eyeball, hidden behind the eyelids.

Radiography, moreover, gave negative results, and revealed no bony damage.

May 10, 1915, intending to proceed with enucleation of the right eyeball, the eyelids were carefully incised at the line of mutual adhesion. Immediately a greenish liquid, holding in suspension some purulent clots, flowed out in abundance.

After having enlarged the incision it was seen that we were dealing with an intra-orbital meningeal cyst, producing under tension a hernia behind the palpebral curtain.

The cerebro-spinal liquid having escaped, we could see, at the bottom of the orbital cavity, the cerebral substance to which a large opening in the orbital vault gave free passage. No trace of the eyeball. Immediate suture of the operation wound, after drainage.

The same evening the pulse slowed down, the patient became delirious, and the temperature rose to 39·8° C. (103·6° Fahr.). Symptoms of meningo-encephalitis appeared, and R. died May 12, 1915, from suppurative meningitis; the cerebro-spinal fluid withdrawn after puncture contained pus in great quantity.

The first patient, as a result of serious injury to the temple which necessitated trephining, presented only certain troubles in the nervous system, vertigo, deafness of the left side, cutaneous anæsthesia of the left side

of the face, disappearance of the plantar and tendo Achillis reflexes, and diminution of visual acuity of the left eye. The subject of Case 62 presented a large loss of substance in the left parietal region, with, as the only cerebral disorder, an aphasia which disappeared completely after trephining. The patient in Case 63 was wounded by a large piece of shell which lodged behind the left zygomatic process and the mandible; at the time of extraction of the projectile cerebral matter appeared; a probe introduced into the opening passed through the fractured wing of the sphenoid into the temporal convolutions, far from the eyeball. From the time of his admission under our care the patient had crises of delirium, preceded by pains in the head and a sensory aura (sensation of an unpleasant smell); the crises were not accompanied by loss of consciousness, but by amnesia, pallor of the face, and difficulties of speech He had also serious disturbances of vision; there was acute optic neuritis on each side, and we have grave fears for this patient's future, at least so far as his eyes are concerned.

Case 65 is still more interesting; the patient was struck by portions of grenade, which, after having destroyed the eye and smashed up the roof of the orbit, came to rest in the brain (Figs. 62 and 63). They produced phenomena of meningo-encephalitis, with an abscess under the frontal lobe. We performed an operation consisting in the detachment of the whole of the periosteum of the orbital vault; a large fragment was removed, and, as in an atypical trephining, the edges of the opening resulting from the loss of substance were rounded off in such a way as greatly to enlarge it; a large quantity of pus flowed away. The cerebral phenomena related in the notes slowly disappeared, and the patient recovered, apparently retaining without damage, at least for the present, the two intra-cerebral foreign bodies which are seen in Figs. 62 and 63, and which the radiogram reveals clearly.

We also draw attention to another case of fracture

of the left orbital vault with loss of cerebral substance, in which recovery was readily obtained without inflammatory mishaps and without cerebral disorders of any kind.

It was not so, unhappily, with the last case, which terminated by death. An unsuspected fracture of the orbital vault was present in a patient coming under our care from a distant centre; he had a fracture of the superior orbital margin; radiography showed neither lesion of the roof of the orbit nor foreign body, and we felt in the orbit a soft swelling, so deep that it appeared to us to be a shrunken eye. In attempting to remove it we opened a cyst, filled with a suspicious serous fluid, communicating with the cranial cavity, and the patient rapidly succumbed to meningo-encephalitis. It is the only unfortunate case of this kind we have met with.

## *CHAPTER VI*

## TREATMENT OF FRACTURES OF THE ORBIT AND THEIR COMPLICATIONS

THE immediate treatment which the military surgeon at the front should apply to fractures of the orbit will not detain us long; the first reason is that we have been working far removed at the base, for the past thirty months, and we have only seen fractures of which the most recent were several weeks old; the second reason is that in reality it is the complications of these fractures which present special indications.

The fractures themselves require, as a rule, only the ordinary attentions of antisepsis and asepsis, flushing with hydrogen peroxide, the application of tincture of iodine followed by an appropriate dressing, without prejudice to the immediate injection of anti-tetanic serum.

The most important question which arises is to know when it is permissible, in order to ascertain the extent of the mischief, to probe the track of the projectile; the best principle is to abstain until such time as carefully executed radiography has permitted the offending foreign body to be localised, and thus enabled the surgeon to appreciate exactly the dangers inherent to searching for it and the advantages which may follow its extraction.

It will be well to point out here the immediate steps to be taken in the different fractures of the orbit, according to the region injured.

## Plate I

*Ophthalmoscopic appearances, direct method.*

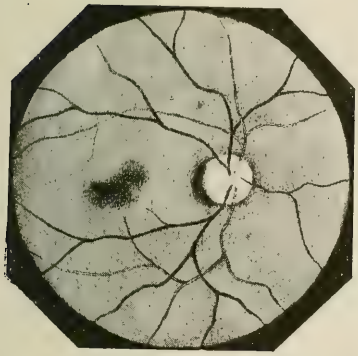


Fig. 1.—R. E. Fracture of left frontal region, severe concussion, hæmorrhage into the sheaths of the right optic nerve, right macular hæmorrhage.

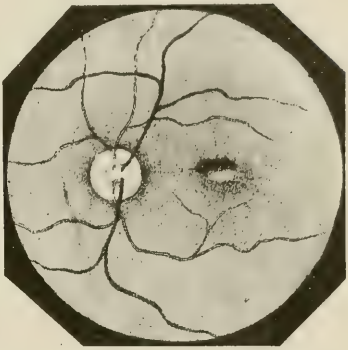


Fig. 2.—L. E. Fracture of left orbital arch and outer margin, concussion of tissues of orbit, macular hæmorrhage, optic atrophy.

Fig. 3.—R. E. Fracture of floor of orbit and of right inferior orbital margin; macular choroido-retinitis (concussion lesion); atrophic and pigmented choroido-retinitis (contact lesions).

Fig. 4.—R. E. Fracture of the external orbital margin; macular and peri-papillary choroido-retinitis (concussion lesions).

## Plate II

*Ophthalmoscopic appearances, direct method.*

Fig. 1.—L. E. Fracture of ascending process of malar bone and of infero-external orbital margin; macular hæmorrhage and choroido-retinitis (concussion lesions).

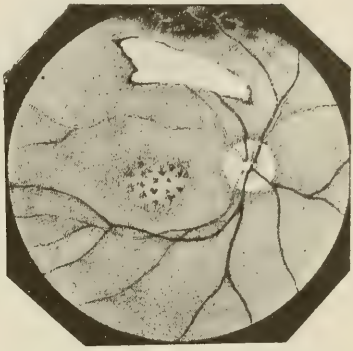


Fig. 2.—R. E. Fracture of frontal sinus with depression. Macular choroiditis (concussion lesions); choroido-retinitis above and to the inner side (contact lesions).

Fig. 3.—R. E. Fracture of the malar bone and of the inferior orbital margin; macular choroido-retinitis, rupture (concussion lesion); choroido-retinitis and detachment of the retina (contact lesions).

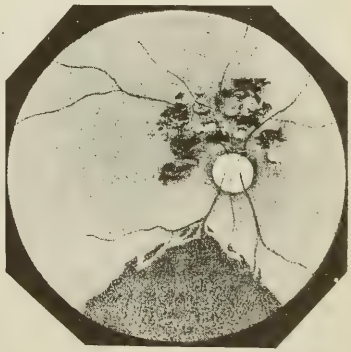


Fig. 4.—R. E. Fracture of the floor of the orbit; peri-papillary choroiditis (concussion lesion); hæmorrhage and pigmented choroido-retinitis below (contact lesions).

## Plate III

*Ophthalmoscopic appearances, direct method.*

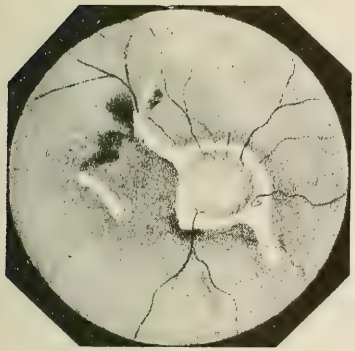


Fig. 1.—R. E. Fracture of the external orbital process and wall of the orbit; avulsion of optic nerve, deep excavation.

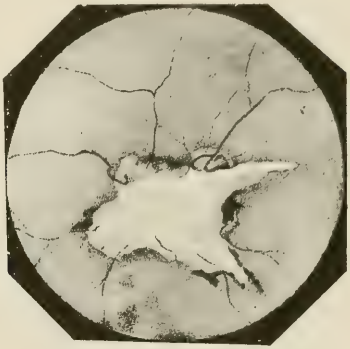


Fig. 2.—L. E. Fracture of external orbital wall, bullet having traversed the orbit; partial avulsion of optic nerve; below, traumatic proliferating choroido-retinitis.

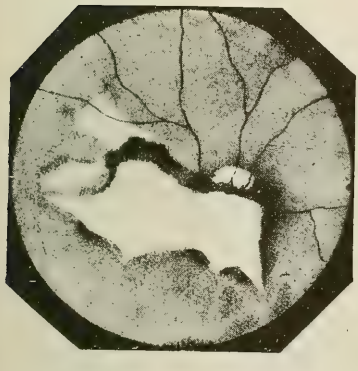


Fig. 3.—R. E. Fracture of facial bones; traumatic proliferating choroido-retinitis.

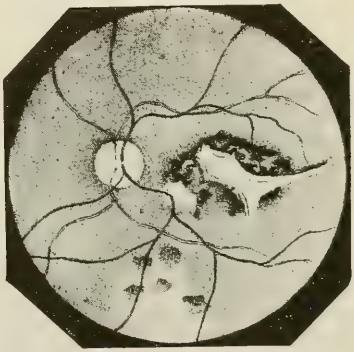


Fig. 4.—L. E. Fracture of the external orbital wall and inferior margin; laceration of the retina and choroid in the macular region (concussion lesion); proliferating choroido-retinitis; atrophic and pigmented choroido-retinitis below (contact lesion).

## Plate IV

*Ophthalmoscopic appearances, direct method.*

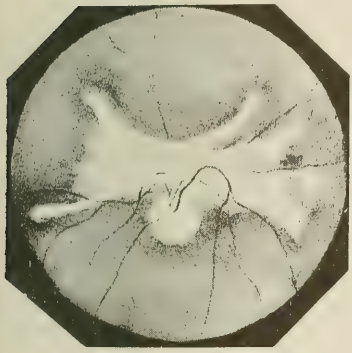


Fig. 1.—L. E. Fracture of the superior orbital margin; intra-orbital foreign body, section of optic nerve; proliferating choroido-retinitis of the superior papillo-macular region.

Fig. 2.—R. E. The projectile has traversed the facial bony mass without touching the right eye: laceration of the right macular retina and choroid; proliferating choroido-retinitis (concussion lesion).

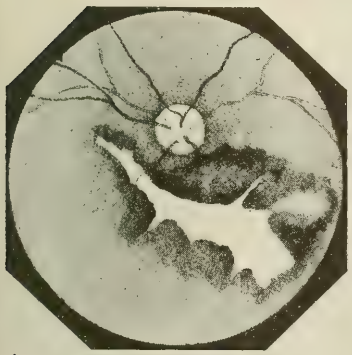


Fig. 3.—L. E. Fracture of the inferior wall of the orbit, with propulsion of the bony fragment towards the eye; large laceration of the retina and choroid (contact lesion).

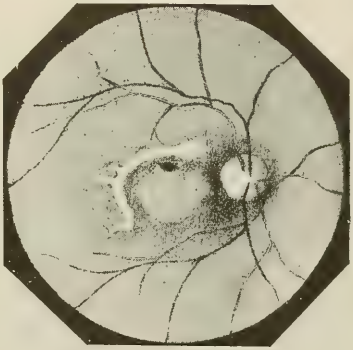


Fig. 4.—R. E. Fracture of the external orbital wall; rupture of the choroid in the macular region (concussion lesion); proliferating choroido-retinitis.

## Plate V

*Ophthalmoscopic appearances, indirect method.*

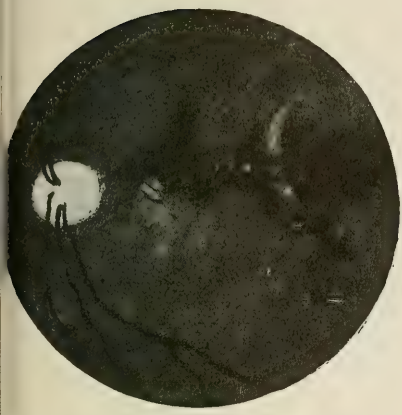


Fig. 1.—Case 31. The laceration crossing the choroid can be detected in the midst of the abundant pigmentation which covers the macular region (concussion lesion).

Fig. 2.—Case 32. Note the retinal vessels passing above the choroidal lacerations. One is interrupted in its course and is covered by a tract of proliferating retinitis (concussion lesion).

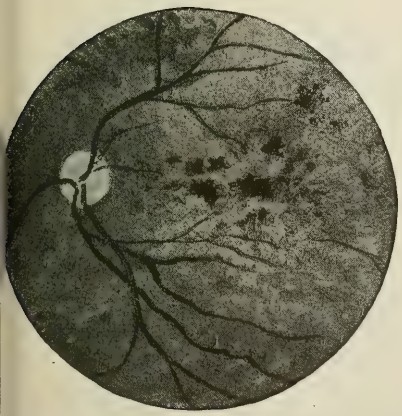


Fig. 3.—Case 33. The pigment here probably conceals fine choroidal lacerations (concussion lesion).

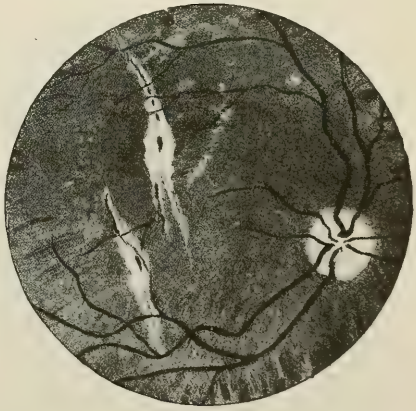


Fig. 4.—Case 34. The retina is intact at the site of the choroidal lacerations, as demonstrated by the vessels (concussion lesions).

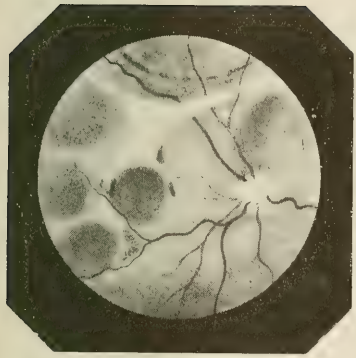


FIG. 1.—Case 16. The retina itself has been torn, like the choroid. Examination of the vessels furnishes the proof.

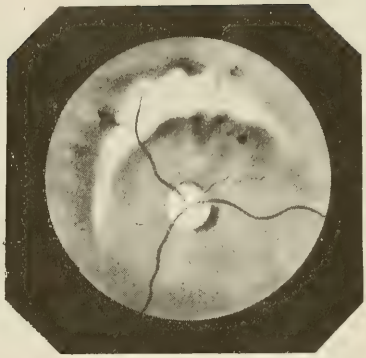


FIG. 2.—The disc is atrophied; a vast laceration of the choroid has destroyed the macular region; the bullet has divided the optic nerve, traversing the orbit without touching the eye (concussion lesion).

FIG. 3.—Case 37. The macular region is the seat of a vast choroidal laceration surrounded by pigment (concussion lesion).

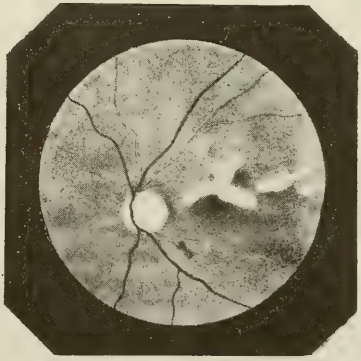


FIG. 4.—Case 38. The posterior myopic staphyloma is doubtless an old lesion; but the choroidal laceration in the macular region is due to traumatism (concussion lesion).

We shall not speak of the treatment indicated in indirect fractures, because these fractures do not exist in military surgery. We do not contest their existence in civil surgery; falls on the cranium may produce radiations over the orbital vault, but gunshot fractures of the skull do not lead to such radiations, and in this chapter on therapeutics we need not concern ourselves with them.

The immediate care to be devoted to direct fractures will alone occupy us; we shall consider successively fractures (*a*) of the superior margin and wall, (*b*) of the internal margin and wall, (*c*) of the inferior margin and wall, and (*d*) of the external margin and wall.

### (*a*) Superior Orbital Margin and Wall

If a simple, not compound, fracture be in question, a light compress suffices. If there is an open wound any detached fragment should be restored to its place, after ensuring good asepsis. Delorme judiciously advises that all splinters of bone which are in the least adherent should be left, and only free portions removed. Further, great care must be taken in the removal of splinters and the cleansing of the wound when the eye is still present; we shall return to this later.

It should be remembered that fractures of the superior orbital margin and walls are less serious than those of the superior wall alone. De Wecker is of opinion that when the vulnerant force has broken both the margin and the wall the shock is deadened and reacts less seriously on the brain. It is also possible that fracture of the margin renders the natural drainage more efficacious and facilitates the escape of the septic discharges which are easily retained in a narrow, concealed fracture of the orbital wall. It is certain that one sees such fractures, at first apparently not serious, terminate rapidly in death. Dupuytren has already noticed under these circumstances the apparent benignity of the external wound, and amongst

the four cases of this kind reported by MACKENZIE there is one in a subject who, wounded by a sword in the left orbit, walked two leagues, ate with good appetite, feeling no pain, and then died the next day; his wound had penetrated to the brain. ROLLET recalls similar cases from DIEMERBROECK, GAYET and ARLOING.

BERLIN has laid great stress on the frequency of these rapid deaths after fracture of the roof of the orbit, quoting cases of immediate death due to the rupture of large vessels; but he brings especially into relief the part played by meningo-encephalitis, which appears from the third to the sixth day, and should therefore be borne in mind by the surgeons at the front who are charged with the early treatment.

In the presence of such injuries the surgeon should examine very attentively both the local conditions and the general state of the patient, and regard these small orbito-palpebral wounds very seriously from the outset. As soon as possible he should endeavour to have the subject radiographed, before any surgical treatment has been adopted; but if this preliminary measure is impossible it need only to be regretted so far as concerns the possible presence of a foreign body. Radiography, unhappily, will give no information as to fractures of the orbital vault; fractures in themselves extensive, with splinters of small dimension, pass unperceived; we have often been astonished at the impotence of X-rays in this respect. It is, however, a clinical fact which must be accepted and made the best of.

Hence the subject's general condition and the cerebral symptoms should be the basis of treatment. If the inflamed wound appears soiled, if there is fever, prostration, pains in the head and so on, there must be no hesitation in exploring the wound, cleansing the track and opening it up, so as to enable the discharges to flow away freely.

### (*b*) Fractures of the Internal Margin and Wall

All the general considerations already mentioned apply to these fractures; so far as they are specially concerned, if the bones are smashed in, some attempt should be made to replace the fragments in good position. Hippocrates has already advised that the reduction be made by means of a finger introduced into the nostril; military surgeons have used an elastic cannula (Boyer) or a metallic tube (Charles Bell). Rollet, after Molière and Chandelux, advises replacing the fragments with the fingers and rounded instruments, employing anæsthesia if necessary, and maintaining the fracture in position by a gutta-percha appliance. Later, attention must be paid to the state of the lacrymal passages, which are usually obliterated, and attempts must be made to re-establish their permeability.

### (*c*) Fractures of the Inferior Margin and Wall

When the malar bone is comminuted and driven in it will sometimes be possible to elevate the fragments, replace them, and so reconstitute the prominence of the cheek. The patient thus avoids the necessity for a later reparative operation. This elevation of the malar bone may even be effected a long time after the accident; Gayet and Cl. Martin (of Lyons) have succeeded in raising the malar bone and fixing it in its normal situation with platinum pins.

When the case first receives attention, the military surgeon should always bear in mind that the bones of the orbit are endowed with great vitality; not only should fragments of bone which possess any shred of adhesion not be removed, but it is advisable to replace completely detached bone in good position and graft the splinters in their normal situation, covering them with the soft parts.

### (*d*) Fractures of the External Margin and Wall

The same rules will again inspire action here; the external orbital arch, if it is fractured and thrust in one or more pieces into the temporal fossa, must be put back in its place and preserved as much as possible. When the external wall is involved, the fracture is deeply placed at the bottom of a thick layer of muscular tissue; there must be no timidity in incising soft parts, both in order to seek splinters and foreign bodies in the wound, and also to facilitate the escape of discharge.

Nearly allied to these isolated fractures of the various borders and walls of the bony framework of the orbit are the comminuted fractures involving several of the walls, and here Larrey's well-known case may be recalled, in which the subject was struck on the face by a cannon-ball which carried away the whole of the lower jaw, the bones of the nose, the ethmoid, the two malar bones, and the zygomatic arches. In gunshot suicides, when the weapon is placed under the chin, the authorities in forensic medicine have frequently recorded similar disasters; the rules given on the subject of the treatment suitable in such a case follow from the principles and the special rules already referred to. The clinical instincts of the surgeon will here have full play.

To indicate with more detail the treatment to be followed we will now study what steps should be taken at the outset in fractures of the orbit according as: (1) the eye is preserved; (2) the eye is destroyed; (3) the neighbouring cavities are implicated; (4) a foreign body is or is not retained.

### (1) The Eye is Preserved

If the eye is preserved it is necessary, above all, to do nothing which will compromise the mobility or the vitality of the globe.

Thus, as has been said above (pp 872*et seqq.*), the eye

is very often proptosed as the result of an intra-orbital hæmorrhage, which thrusts it forcibly forwards and will not allow the eyelids to cover it. It will be necessary by means of an appropriate dressing simply to close down the eyelids in front of the eye. If this cannot be done it will be well to reduce the exophthalmos by cautious aseptic incisions, made in the lower part of the orbit, in such a manner as not to injure the muscles, and keeping as far as possible away from the levator, which is less able to endure the traumatism of the scalpel than the extrinsic muscles of the globe. Unless the ophthalmic ganglion, that "little brain of the eye," be destroyed, we shall always be able to avoid inflammatory phenomena of the cornea, and, in the absence of lagophthalmos, the organ of vision is easily preserved.

If the blood clot should suppurate, it will be necessary to lay open more freely and drain in such a way that the pus may easily escape; the result may still prove very satisfactory.

### (2) The Eye is Destroyed

If the eye is destroyed, the surgeon is relieved of anxiety; when the scleral wound has been large enough to permit a free escape of vitreous body, he will enucleate the globe without hesitation. Such an eye is destined to become nothing more than a dangerous withered stump, often painful, ready to stir up mischief; reserving further remarks on the subject later, we may say here that such a globe is nothing but an enemy to the other eye, and consequently to the patient. We think it is not wise to be contented with evisceration. Doubtless it is quite true that a carefully performed evisceration, in which absolutely no trace of the uveal tract is left behind, presents no dangers; but often, in the unavoidable haste imposed upon an operator at the front by the multiplicity of his duties, this evisceration will be hurried, and harmful débris of the choroid or ciliary body will

be left in the scleral sac. Further, evisceration is accompanied by more or less purulent secretion of considerable duration. A classic enucleation, within TENON'S capsule, quite according to rule, cutting the optic nerve level with the eye, is the operation to be chosen. We recommend it urgently to all our surgical colleagues into whose hands fractures of the orbit fall in the first instance, when the eye has been crushed, torn, or simply laid widely open by the projectile.

The eye once removed, nothing more is to be feared in the orbit, if after the operation antiseptic lavage is used, cleansing the orbital cavity according as the degree of infection requires.

The ophthalmic surgeon may here turn to good account the discussions which have taken place concerning CARREL'S method; it is not our place, nor our pretention, to guide those who are worthy to wield the scalpel. We say simply that, in such circumstances, free opening-up, to allow liquids to escape, free ablutions with hydrogen peroxide, and daily lavage with 7 per 1000 saline solution, are the means which we consider at the same time necessary and sufficient for success.

### (3) FRACTURES IMPLICATING THE NEIGHBOURING CAVITIES

A problem of diagnosis arises here which is not easy to solve. Radiography does not give complete satisfaction on this subject; a fracture of the orbital vault is passed over easily, we may even say always escapes unnoticed; we are in this respect much less fortunate than the surgeons who deal with fractures of the limbs, for whom radiograms reveal the smallest crack; and it will be necessary, when dealing with a serious fracture of the orbit with or without loss of the eyeball, to inquire into all the ordinary clinical signs of extension to the brain.

When the projectile has to a great extent destroyed the roof of the orbit and penetrated into the cerebral

cavity one must not expect to see in every case the evidences of mischief burst forth immediately; they only come about consecutive to orbital infection, which is propagated secondarily, by way of the breach itself, to the encephalic mass. This is what took place in a very interesting case published by MORAX in his report of Oct. 1915. A soldier, wounded Sep. 27, 1915, went to the Lariboisière hospital, Oct. 10, with the diagnosis of bullet wounds which had caused fracture of the walls of the orbit, the nasal bones, and the anterior margin of the frontal, with rupture of the eyeball. The wound, which was very large, had been plugged with sterile gauze, and there was neither suppuration nor fever. On Oct. 12 no change had taken place in the condition of the wound; on the evening of the 12th, rise of temperature, vomiting, pains in the head; Oct. 14, pains in the head, great stiffness of the neck and Kernig's sign; lumbar puncture yields a turbid liquid; the 17th, death with signs of acute meningitis. The autopsy showed a fracture implicating the anterior floor and suppurative inflammation between the dura mater and the right frontal lobe.

With this case of MORAX'S we might compare VALUDE'S, wound by rifle bullet at the supero-external portion of the right frontal bone, with escape of cerebral matter by the frontal wound; there had been an abscess of the eyelid and keratitis with hypopyon. All seemed to be going well until encephalic infection set in, and the patient died. (Report of Jan. 1915.)

With these should be compared the report, quoted above, of a case in which the patient was enabled to recover, thanks to an operation done, late enough it is true, since the subject already presented serious cerebral symptoms, but as quickly as possible; we performed in this case an atypical trephining of the cranium by the orbital route. (Case 65.)

VALUDE was also fortunate in a case in which radiography showed a sub-cranial bullet beyond the

orbit. Enucleation had been performed, but the projectile, well tolerated, had not been extracted; it soon gave rise to serious symptoms of infection, œdema of the eyelids, and chemosis; VALUDE interfered, and removed the offending projectile from a depth of six centimetres, in lardaceous tissue; the patient recovered. (Report of April, 1915.)

The conclusion of these remarks is that, if infectious orbital and para-orbital phenomena appear after a fracture, the offending body must be at once looked for; we recommend that the periosteum of the orbital vault be detached with care, because of the thinness of the wall. Also, should a fracture exist which the radiogram does not show, the septic fluids may escape by way of the orbit, if it is well laid open and thoroughly cleansed. If in the course of the operation a fracture of the vault is met with, the roof must be trephined and a free communication thus established between the anterior encephalic region and the orbital cavity. In short, it is necessary to act in the presence of cranial fractures implicating the orbit as the surgeon is accustomed to act in fractures of the cranium in general. At the first sign of extension to the encephalon, or if it is suspected, one must act at once.

Moreover, we should add that the diagnosis of encephalic disorders coinciding with fractures of the orbit is far from being always easy, and that from this point of view we may meet with surprises, the more so since the best radiograms, as has already been said, give very little information in this kind of bony disturbance. We shall never forget the cruel misfortune which happened to us in Case 66, in which no encephalic symptom of any kind appeared, in which radiography showed nothing definite, and which presented, with a symblepharon of the upper eyelid, a fairly hard intra-orbital tumour, slightly resistant, which we believed to be the remains of the eye, destroyed by the injury. We set about removing this débris; at the first stroke of the scissors, sero-purulent liquid poured out, and at the bottom of the pouch

we found the pulsatile encephalic mass; in spite of careful antisepsis, a meningo-encephalitis developed which rapidly carried off the patient. There was nothing to warn us in the history of the patient, wounded a long time previously, nothing in the examination of his radiogram, or in any of his symptoms, to suggest that there might be free communication between the orbit and the cranium.

After these cases of orbital fracture, remarkable for the importance of their intra-cranial complications, it will be well to cite less serious cases, in which, in spite of evidence of cerebral disorders, infectious accidents being absent, it has not been necessary for the surgeon to interfere. We have noted cases in which the orbital fracture was accompanied only by optic neuritis, vertigo and anæsthesia of the face with intermittent headache.

In one case, after injury by a large piece of shell, lodged behind the left zygomatic process and the process of the mandible, there was escape of cerebral matter from the wound, and there occurred neuritis (choked disc) and epileptiform attacks which did not appear to warrant fresh interference (see Case 63).

After the fractures of the orbit implicating the cranial cavity, let us consider for a moment those which concern the maxillary and frontal sinuses. These are infinitely less serious; two classes of cases must be distinguished: (1) those in which the lesion of the sinus is accompanied by the presence of a projectile; (2) those in which there exists simply a sinusitis without retained projectile.

When a projectile is present it should be extracted without delay. Nothing is simpler; we will not quote all the cases in which we have been able to interfere under such conditions: it will be sufficient to recall here the cases quoted above (pp. 949 *et seqq.*), and to note amongst the foreign bodies we have found in the sinus the eye itself, luxated by the traumatism and thrust through the fracture in the floor of the orbit into the antrum.

The frontal sinus is less frequently injured than the antrum, and we have never found a foreign body in this cavity, but it is sometimes implicated by a projectile which ruptures its anterior wall, in such a manner that an unsightly depression results. In several cases of this kind, we have been able to fill up the cavity by the aid of an adipose graft, which has given a satisfactory result (see pp. 957 *et seqq.*).

In another case, quite analogous to these, and remarkable for destruction of the pulley of the superior oblique, the patient refused to have an adipose graft, which appeared to us under such circumstances highly desirable. We shall return later to this type of intervention, publishing some successful cases from our practice.

### (4) Presence of a Foreign Body

When there is a foreign body in the orbit or in the neighbouring cavities it is not always necessary to extract it; it is certain that very often these foreign bodies, quite aseptic and fortunately situated, may be well tolerated. When they are situated in the cranial cavity they merit particular respect if they are giving no trouble; it is precisely the type of case in which the practitioner should rely upon his clinical sagacity. When the foreign body is in the orbit or in the maxillary antrum the surgeon's perplexity becomes much less; *a priori* it should be removed, however small it may be.

To remove a foreign body, well localised by radiography, from the maxillary sinus it is well to use the aperture made by the projectile if it is well in evidence; if not, open out the anterior wall of the sinus without hesitation, taking care of the infra-orbital nerve; the foreign body may be easily picked out of the sinus, which at the same time should be thoroughly cleansed and drained by the side of the nose.

When the foreign body is in the orbit two conditions must be distinguished, according as the eye is preserved

or destroyed. When it is destroyed nothing is simpler than to take hold of the foreign body by means of ordinary instruments, sparing as much as possible everything which is of importance for a good prothesis, especially the levator muscle of the eyelid. When the eye is intact, at least in appearance, it is indispensable to remove the foreign body without disturbing the eye. If the foreign body is in the anterior region of the orbit an incision of the soft parts will often suffice to

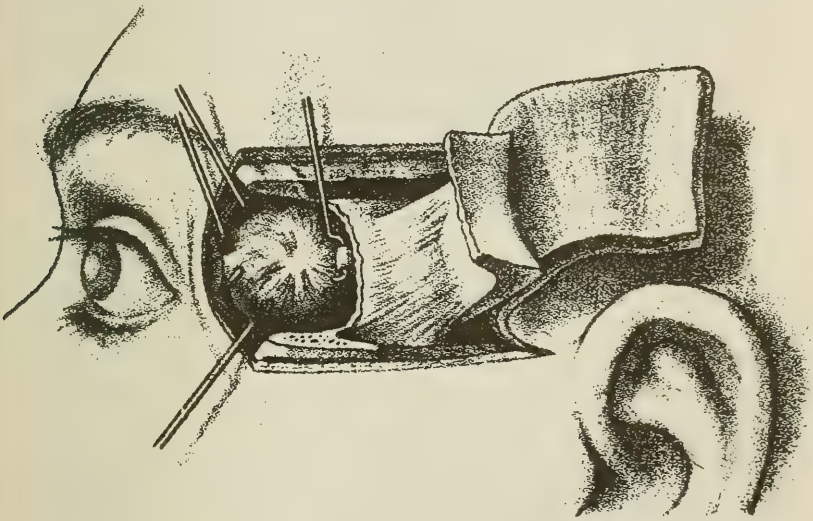


Fig. 64.

give the surgeon access to it. For the search, help is obtained of the electro-magnet and all the means of extraction in use in ordinary surgery; but when the foreign body is retrobulbar and deeply buried, there must be no hesitation in having recourse to Krönlein's operation, which we have no need to describe here, and which Fig. 64 will adequately recall to our readers.

When the foreign body is situated on the ethmoid side, in the internal region of the orbit, we recommend the operative procedure we have elsewhere advised for the ablation of certain orbital tumours placed to the inner side of the optic nerve. It is an advantage in this

case to mobilise Krönlein's flap, in order to be able to throw the eye outwards towards the external wall of the enlarged orbit (Fig. 65); by this device one has room to operate and *the ophthalmic ganglion is not touched,*

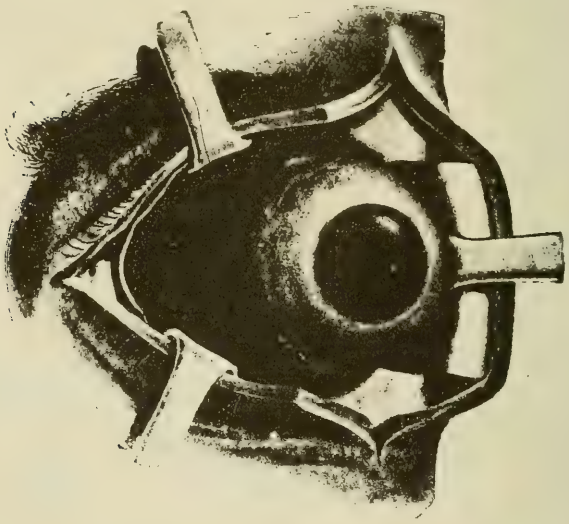


Fig. 65.

a most important organ to be considered when it is desired to preserve the eyeball intact.

The reader will have already found in this work reports of cases in which Krönlein's operation has been performed with extremely favourable results (see pp. 844 *et seqq.*).

## *CHAPTER VII*

## TREATMENT OF OCULAR COMPLICATIONS

The principal ocular complications which merit our attention are —

(1) Sympathetic ophthalmia.
(2) Traumatic cataract.
(3) Detachment of the retina.

### (1) Sympathetic Ophthalmia

Projectiles of war fracturing the orbit often involve the eyeball, either by penetrating into its interior or by rupturing its envelope and so destroying it. To our great surprise, as we have said elsewhere (p. 891) we have not met with a single case of partial rupture of the sclerotic, permitting the eye to survive and to keep its appearance after such an injury.

When the eye is implicated to this degree by the projectile its shape is destroyed, the greater part of the vitreous body is expelled, and the surgeon is immediately faced with a stump more or less large, more or less inflamed, more or less torn, and whose future is the cause of great anxiety.

Two questions here present themselves :—

(1) What should be done with an eye which has a foreign body in its interior ?

(2) What should be done with an eye whose membranes are ruptured, and which, without a retained foreign body, has at the same time absolutely lost its outward appearance, and also its visual power irremediably ?

These two questions are serious because they involve

that subject, so distressing and still so much discussed by surgeons, sympathetic ophthalmia.

Sympathetic ophthalmia has not been dreaded to the same degree by all ophthalmic surgeons; there are those who do not believe in it, who declare they have never seen it (POULARD). There are others, and we are of the number, who, without considering it frequent, think it is not so rare that we may put it out of our thoughts altogether.

On the subject of its frequency in military surgery, we shall take as a basis abstracts from the reports of the ophthalmic centres which have been published during the past two years by our colleagues in the army. We find there the following evidence.

KALT (Report of Oct., 1915), is astonished at not having met with a single case, in spite of the number of atrophied globes which he has seen as a sequel of penetrating wounds, and it seems, he says, that there is here a discordance with what we observe in civil practice; but it does not happen that all our colleagues have made such a remark. COSSE (Dec., 1914) cites two cases, one of which terminated in blindness, and he notes a third grave case in April, 1915. COUTELA (Report of June, 1915) relates a case occurring seventeen days after enucleation, and two more in his Report of the following month; these cases, relatively benign (the attenuated ophthalmia of DE LAPERSONNE) recovered, but they presented real gravity. We must therefore resort to enucleation neither too much nor too little, says COUTELA. TERRIEN holds a similar opinion; he has performed, in order to prevent sympathetic ophthalmia, a relatively large number of enucleations and optico-ciliary neurotomies.

Among the cases of sympathetic ophthalmia published by the directors of the centres of military ophthalmology we should especially mention a case-report published by TEULIÈRES (Report of Feb., 1916) concerning a simple contusion of the eye without foreign body and without wound; enucleation of the atrophied stump on the right side controlled the affection whose sympathetic

origin was thus well established. Such cases are so rare that it is perhaps permissible to believe that there existed a small conjunctival wound, which passed undetected before the patient was submitted to the examination of our colleague.

To these cases we shall add the very interesting one reported by MORAX in June, 1916; it was a question of an operation for traumatic cataract; a prolapse of the iris had occurred which had been cauterised. Sympathetic ophthalmia resulted, not, to define it exactly, from the extraction of the lens, but from faulty cicatrisation after the latter operation.

Such is a rapid enumeration of the principal cases published during this war in the reports of our colleagues; doubtless others, in considerable numbers, have not been mentioned; we have a proof of the frequency of accidents of sympathetic origin in the work just published by DR. COUSIN, aide-major attaché au centre de la 9e Région; this author gives sixteen cases in which he has found sympathetic reactions following injuries of war; these sympathetic reactions are not ophthalmia, since after all there is no inflammation, no serous iritis as in attenuated sympathetic ophthalmia; but we say without hesitation that photophobia, lacrymation, fatigue in reading, and diminution of visual acuity, are the first degree of the affection, of which serous iritis is the second degree and of which irido-cyclitis is the third. All this pertains to sympathetic ophthalmia, and it is a misfortune if a patient, thus attacked, is under the care of an operator capable of hesitating and putting off the enucleation.

In our centre of military ophthalmology we have also met with cases of sympathetic ophthalmia amongst the cases sent to us; we shall not report them in detail in order not to overweight this chapter, which must be short.

Out of 2554 injuries involving the eyeball we have seen five cases of sympathetic ophthalmia. In the first four cases it was a matter of a perforating wound of one of the globes in the ciliary region, with presence

of an intra-ocular foreign body. Sympathetic iridocyclitis made its appearance on one occasion fourteen days after the traumatism; in the next case, forty; in the third case, nineteen; in the fourth case, thirty-two days after the injury.

In these four cases, prompt enucleation at the outset brought about complete recovery in three; the fourth had a relapse which yielded to treatment.

The fifth case was that of a soldier, wounded on Oct. 11, 1915, upon whom Dr. Lataillade performed evisceration of the right eye for panophthalmitis following a perforating wound, and which, on Nov. 7, 1915, presented optic neuritis of the left side, probably of sympathetic nature.

Enucleation of the right stump and its dissection revealed a small fragment lodged in the scleral envelope in contact with the optic nerve. Improvement of the neuritis followed very rapidly. The case has been, moreover, reported above.

What, therefore, is the course to take—

(1) In the case where the injured eyeball contains a foreign body?

(2) In the case where there is an eye, without a foreign body, but profoundly damaged, completely deprived of sight, after an open wound?

We expounded our views on the subject of the first case at the meeting of the Société française d'Ophtalmologie, April, 1916.

If the eye containing a foreign body has still useful vision it should be spared.

When it no longer has vision two classes of conditions must be considered:—

(1) The foreign body is in the ciliary region.

(2) The foreign body is in the eye, but outside the ciliary region.

If the foreign body is in the ciliary region of an eye deprived of vision, however good may be the appearance of the eye, even when the patient complains of no pain and no symptom of irritation it is necessary to enucleate the eye.

If the foreign body is not in the ciliary region and the eye is quite intact, neither irritable, nor painful, nor reduced in tension, the eye should be spared, at the same time warning the patient that, in the future, things may not always go so well.

If, on the contrary, the eye containing the foreign body elsewhere than in the ciliary region is reduced in tension, a little tender on pressure, if its nutrition is visibly suffering, it should be enucleated without delay, and not be allowed to leave the other eye in such a dangerous neighbourhood.

These are the rules which I should like to see officially recommended to surgeons who, without being ophthalmological specialists, are often forced by circumstances to treat wounds of the eye; and also to the younger ophthalmic surgeons, who are not yet fully experienced.

It is expedient that everybody should be able, in the case of intra-ocular foreign body, to do an enucleation at the fitting time; and, in my opinion, the time has come to formulate general practical rules which can be utilised in everyday clinical work.

The same rules are applicable to the second class of conditions. If the eye has still a satisfactory appearance, if its volume has been almost completely preserved, its diminution of tension moderate, its ciliary region insensitive to the touch, then it may be kept. But when it is the seat of a manifest cyclitis, of long standing, with evident inflammatory reaction, however slight this latter may be, and having resisted appropriate treatment for several months, one must not hesitate to consider the eye dangerous; much more so when in presence of an atrophied stump resulting from an open wound.

In this question of the treatment of sympathetic ophthalmia and with the views which we have laid down we take our stand, therefore, on the side of the enucleators. Enucleation of the globe renders great service with a minimum of inconvenience, and, in fact, the horror which certain of our confrères have of this operation makes us think of the ostracism with which

the Athenians sentenced Aristides because they were weary of hearing him called "the Just."

### (2) Traumatic Cataract

Amongst the complications of fractures of the orbit which may arise in the visual apparatus it will be well to give a place to the injuries which bring about luxations or cataracts.

Here we shall be brief, because it is a subject which specially belongs to injuries of the eyeball alone; in fractures of the orbit lesions of the lens subject to ophthalmic surgery are relatively rare.

The first question which arises is, to know when to operate and when not to operate on traumatic cataracts in military surgery.

Our reply is ready: we must operate on these cataracts on the same principle that we operate upon cataracts occurring from industrial accidents in civil life. In restoring sight to a wounded man, we are useful at the same time to the patient and to the employer, and there is no reason for acting otherwise when the patient is a soldier and the employer is the Motherland.

The advantages to the patient are the enlargement of his visual field, the maintenance of the eye in its normal position, and finally the certitude, when the operation has had a fortunate result, that sight will be always preserved, whatever happens to the other eye.

To the State, the advantage is very considerable; these cases are no longer "réformés no. 1" (discharged in the first class) from the moment when the eye operated upon has a vision equal to 1/20; the soldier escapes the law of 1831, and falls under the Decree of March 24, 1915, which provides for a gratuity proportional to the lessening of visual acuity. Instead of a pension of 600 francs, a fairly large sum for the loss of vision of a single eye, the subject of aphakia receives 200 francs, which we consider ample, and moreover it is

in conformity with the tariff of the law of April 9, 1898, concerning occupational accidents; the resultant saving to the State is very great, and deserves to be borne in mind in a quite exceptional manner.

Confronted with the statistics which have been published by a large number of ophthalmologists it is not possible seriously to maintain that intervention in traumatic cataracts yields no results. It is a question simply of doing it at the right time, when it is indicated; that is to say, it is only necessary to interfere in an early stage for glaucomatous accidents due to swelling of the lens, and, apart from these accidents, to operate only on cases which are quite settled down, of long standing, and in which one has good reports as to the state of the deep membranes.

As a general rule, we operate on uncomplicated traumatic cataracts six to twelve months after the injury. When the lens remains entire, a large incision in the cornea, without or with iridectomy, permits the evacuation of the débris, which lavage of the anterior chamber by the aid of Chibret's syringe satisfactorily completes.

If only a more or less thick membrane remains, we look upon the various methods of discission with needle or sickle-knife as evil interference, and as still worse, detachment of the capsule with forceps, so unfortunately advised by Panas; in this method one drags on the ciliary processes, perhaps reviving an extinct irido-cyclitis and compromising the future of the globe. Perhaps it is to this error of technique that one may look for the cause of the disappointments mentioned by some colleagues. The operation of choice in such a case is De Wecker's irido-capsulotomy; through a small subconjunctival scleral incision, two or three millimetres from the limbus, the thickest portions of membrane are divided with De Wecker's scissors with the minimum of traumatism and without loss of vitreous.

We may quote here our results obtained in our "Service central d'Ophtalmologie militaire."

*Traumatic Cataracts*

1. *Traumatic cataracts observed* = 175.
   - Complicated . . . . . 116
   - Uncomplicated . . . . . 59
2. *Number of operations* = 73.
   - Extraction with or without iridectomy . 52
   - Irido-capsulotomy. . . . . 21

Results

(*a*) Acuity superior to 1/20 = 37
- 1/15 . . . . 8
- 1/10 . . . . 6
- 2/10 . . . . 6
- 3/10 . . . . 9
- 4/10 . . . . 2
- 5/10 . . . . 5
- 6/10 . . . . 1

(*b*) Acuity inferior to 1/20 . . . . 25

(*c*) Acuity nil = 11
- Intra-ocular foreign body . 3
- Hæmorrhage into vitreous. 5
- Post-operative irido-cyclitis 3

## (3) Retinal Detachment

The treatment of traumatic detachment does not differ from that of detachments in general.

Iridectomy, opotherapic injections into the vitreous body, removal by puncture of the sub-retinal fluid, and its replacement by sclerosing liquids (tincture of iodine), and electrolysis are not procedures to be recommended, for they provoke a new traumatism, serious to an eye already irritated, and risk arousing inflammatory phenomena which may result in the disorganisation of the ocular media and a consecutive phthisis of the globe.

Amongst the various procedures for treatment of detachment of the retina there is one which for several years we have been particularly able to recommend, and which is our choice; it consists in creating, in the

region of the canal of Schlemm, beneath the conjunctiva, cicatricial tissue obliterating the filtration spaces. We have termed it "colmatage," an operation which consists in dissecting up the whole of the conjunctiva of the intercalary region between the insertion of the recti muscles and the cornea; thus dissected up, the conjunctiva is flattened down upon the cornea, the whole of the region of the canal of Schlemm, up to 5 mm. behind it, is cauterised, and the mucous membrane put back in place and sutured. The newly formed connective tissue, under the influence of cauterisation, obliterates all the lymphatic spaces; the result is a kind of experimental glaucoma.

We have not, however, had to employ this procedure of "colmatage" on our patients, because it is indicated solely in hypotonic, relaxed eyes—a frequent symptom in myopic detachments, which have a physiognomy peculiar to themselves, but rare, very rare indeed amongst traumatic detachments.

The result is, that we are ourselves content with the classic treatment by subconjunctival injections of chloride of sodium, the instillation of atropine combined with compression of the eye, and finally prolonged decubitus in the dorsal position.

This line of treatment gives the most satisfactory results.

Do not, however, let us forget that time is the principal factor in the cure of this clinical entity. It is incontestable, in fact, that prognosis, while sombre, is much more favourable than for the myopic and symptomatic forms of a general affection. Sometimes the disappearance and more often the diminution of the traumatic detachment comes about in a certain number of cases at the end of a lapse of time, varying between five and six months.

Out of 135 cases of detachment with or without orbital fracture, we have observed three cases of complete recovery. There remain in place of the detachment, cicatrices in form of striæ, of whitish coloration. The first case was a man wounded on Oct. 28, 1914, with

a contusion of the orbital right margin, with scleral wound and a large retinal detachment at the infero-external portion; this detachment still persisted on Feb. 28, 1915. Dr. Cantonnet, called later to re-examine the case, noted the complete disappearance of the lesion, and we ourselves on Oct. 30, 1915, confirmed the complete recovery. The second was described in Case-report 2. The third patient, with a detachment at the infero-external portion of the left eye, after contusion, was well seven months after the traumatism.

Associated with these repositions of the retinal displacement, we have noted eight cases of marked amelioration in the extent of the lesion, in the raising of acuity and in the enlargement of the visual field. The proportion of these favourable results is, as one sees, restricted. To sum up, in 2·2 per cent. there was recovery from the detachment, and in 5·92 per cent. simple amelioration. It is well always to be on one's guard concerning the acuity admitted by patients, for it is certain that many of them are but little disposed to make known their true visual acuity. After the war, when the wounded men are no longer prompted by the hope of a gratuity or a discharge we shall know the truth better.

## *CHAPTER VIII*

# REPARATIVE SURGERY OF ORBITAL FRACTURES

In presence of the great destruction of the soft parts which very often accompanies fractures of the orbit, the malar bone crushed in, orbital arches broken, eyelids lacerated or torn to ribbons, the surgeon must consider how to repair these damages and restore to the wounded man an appearance as pleasing as circumstances admit.

Three dominating principles will be before his mind :

(1) To replace the eyelids in position and restore their normal form as closely as possible.

(2) To restore if possible, and very often it has been possible, the conjunctival culs-de-sac, so as to retain an artificial eye.

(3) To re-establish, so far as may be, the exterior form of the orbit, by filling up gaps in the bone by suitable grafts.

### (A) *Restoration of the Eyelids*

It is unnecessary to write the history of blepharoplasty here. It is contained in all the textbooks, and quite recently it has been excellently retold by our colleague Magitot in the Reports of the Société d'Ophtalmologie de Paris, July 1916.

We prefer the Indian method, as he does, and the short pedicle has always sufficed for our patients in the numerous cases in which we have had to interfere. We have most often used the frontal flap, and when we have had both eyelids to restore, we have fashioned a frontal flap and a malar flap at the same time.

We always found it possible to remake suitable eyelids, and we could quote here a large number of satisfactory results; it seems to us that they do not greatly differ from those which have been obtained by our colleagues in military surgery, and we do not dwell on the point (Figs. 66 and 67).

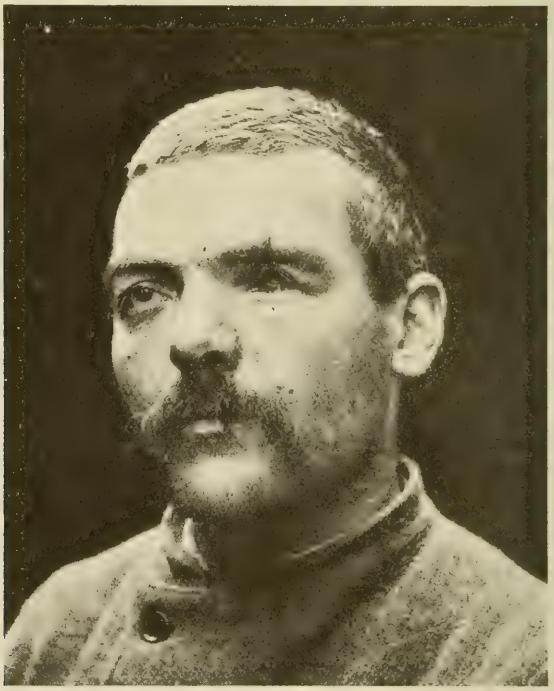


Fig. 66.

(B) *Restoration of the Conjunctival Culs-de-sac*

The restoration of the culs-de-sac is a very interesting question, one of the most difficult in ophthalmic surgery, but we think it is a subject upon which we must not expatiate, as it is only indirectly connected with that of orbital fractures by projectiles of war.

We will simply remind our readers that the essential condition for efficient action is to add to the portion of

conjunctiva which has been preserved a tissue capable of replacing the destroyed mucous membrane. To obtain it, some prefer a dermo-epidermic graft (FRANCK, WEEKS), others a graft limited to the epidermis (MAGITOT); the latter author dissects up from a part distant from the eye, the thigh for example, an epidermic

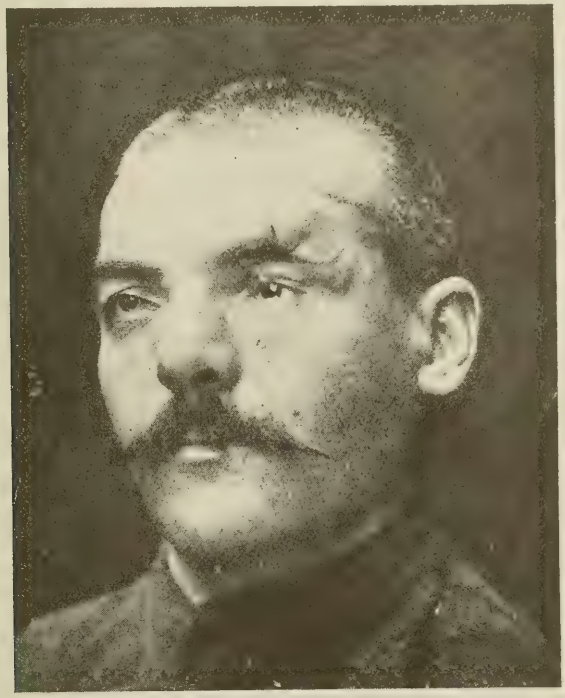


FIG. 67.

flap with which he covers a piece of metal introduced into the orbital cavity in such a manner that the raw surface of the flap is applied to the refreshed surface of the inner aspect of the eyelids. We have had no experience of this latter procedure. We have several times made use of that of FRANCK, with unsatisfactory results, and that is a sufficient reason for trying another method.

With our military patients we have been contented with restoring the culs-de-sac with SNELLEN's sutures, of which we have made large use with great success, varying the form and the situation according to the individual case. We do not include the inferior cul-de-sac, which is often the more at fault and also the more important. We have enlarged, deepened, or even made it anew by splitting the eyelid, as TRUC indicates in his procedure *en vanne*, drawing the internal half of this eyelid forcibly downward by the aid of one or two sutures. The cul-de-sac does not remain as well-marked as at first, but a sulcus deep enough to retain an artificial eye constantly persists. We also believe that lining the lower eyelid with a morsel of skin borrowed from the temple (SNELLEN), the cheek (HARLAN), or the upper eyelid (SAMELSOHN) is worthy of recommendation.

In addition we have recourse to artificial dilatation by pieces of rubber in graduated sizes, inserting successively larger and larger pieces, following the advice given on this subject by DR. COULOMB, and we have had the satisfaction of rendering habitable a large number of sockets which at first seemed as ill-disposed as possible towards receiving a prothesis.

We do not dwell upon this question, for, like that of blepharoplasty, it is on the fringe of the subject, and does not belong, strictly speaking, to fractures of the orbit.

We hasten to discuss what dominates the reparative surgery of these fractures, namely, the treatment of loss of substance of the bony foundation and the re-establishment of the regular contour of the orbit. That is indeed the heart of the subject. The restoration of the eyelids and of the conjunctival sac have little to do with orbital fractures, and such matters as transplantation of labial mucous membrance (CARDO, SIZOREFF), the employment of the skin and cartilage of the ear (BUDINGER), etc., are scarcely germane to the subject.

### (C) *Repair of Damage to the Orbital Walls and in the Bone*

We draw attention to three procedures, of unequal value : (1) metallic plates ; (2) adipose grafts ; (3) cartilaginous grafts.

(1) *Metallic Plates.*—We only know one author who makes use of metallic plates in such circumstances.

Pierre Duval, in a communication to the Société de Chirurgie de Paris (June 16, 1915) presented a case of prothesis of the left frontal and superior orbital margin by means of metallic plates. He used the aluminium plates which are manufactured for military purposes and which are four-tenths of a millimetre thick. The author confesses that this substance gradually becomes absorbed, but the process is usually slow and incomplete. " In a case of extensive depression of the frontal bone," says Duval, " the superior orbital margin was fractured and depressed, save at its extreme two centimetres. I restored it with a plate with a rounded margin anchored by its ends to the osseous margin." The extremities of the prothesis were let into the substance of the diploë at certain points where the operator had made small holes to receive the prolongations. The whole was covered by the refreshed integument. Duval showed the case four months after the prothesis, and the æsthetic result seemed to be most satisfactory, so far as one can judge from the photograph with the publication.

Perhaps we may be able to use in the same way the sheets of rubber advised by Professor Delbet for the restoration of the abdominal walls, but we do not believe that these procedures can bear comparison with the two following.

(2) *Adipose Grafts.*—In order to fill up the orbit and facilitate the wearing of a prothesis, it has long been recommended to graft the split skin with cellulo-adipose tissue ; and long before the interventions necessitated by the war, surgeons were cognisant of the means of filling-out and raising cicatrices which were in vicious position, sunk in and adherent to bone, by introducing

beneath them sufficient fat to transform the excavation into a rounded projection, rather more rounded in fact than seems at first necessary, in order that after the inevitable partial absorption, the aspect of the exterior should be as perfect as possible (VERDERAME, Annales d'Oculistique, 1910). In this

FIG. 68.

war, MORESTIN has made large use of these adipose grafts for the restoration of vicious cicatrices of the face, and the restoring of bony depressions of the orbital margin. In his communications to the Société de Chirurgie de Paris, July 21 and November 24, 1915, he quotes some cases of very extensive facial mutilations, in which a fragment of fatty tissue has been

used to fill up the osseous depressions consequent on injuries to the orbital and peri-orbital bony framework.

We have ourselves under similar circumstances had recourse to the same operation, and can cite several cases in which the result has been very satisfactory.

The adipose grafts should be taken from the subject

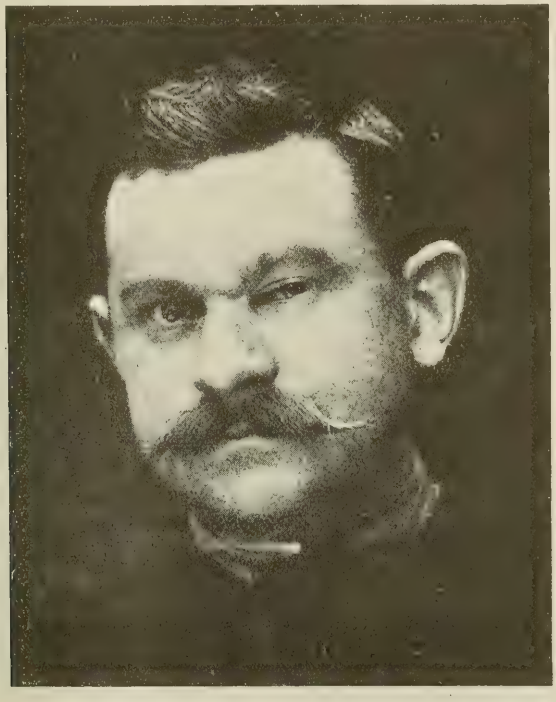


Fig. 69.

himself, from the lower part of the buttock when it is desired to graft adipose tissue, from the thorax if it is wished at the same time to use a cartilaginous graft. In the latter event a single operation on a costal cartilage enables us to obtain at the same time fat and cartilage.

There is always a tendency to resect more fat than is necessary; it is well to ascertain as closely as possible

the capacity of the cavity to be filled, and a graft of dimensions a little greater should be taken. If the adipose tissue presents connective-tissue partitions rather closely packed together so much the better; it is much better to graft cellulo-adipose tissue than pure adipose tissue.

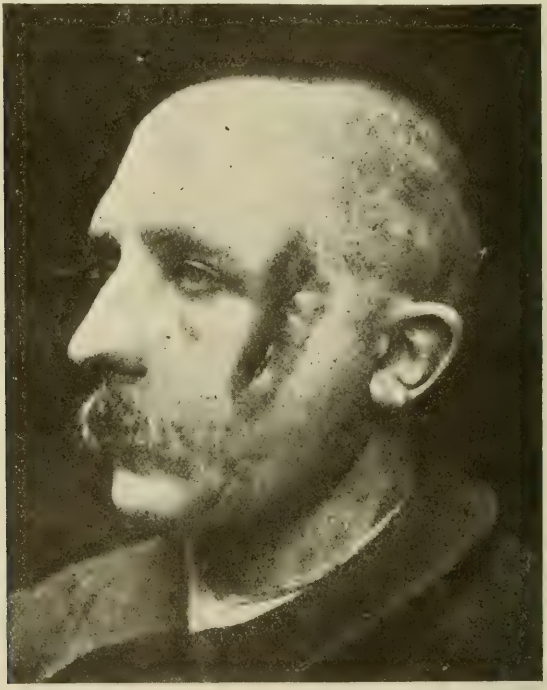


Fig. 70.

The cellulo-adipose graft needs very careful management, for it must not be roughly used. After having prepared it by a rapid dissection, it should be placed in a sterilised cloth and not allowed to undergo any unnecessary handling. The bed in which it is to be placed should be carefully prepared, so that the graft will not come in contact with hard cicatricial tissue, bloodless and without vitality; it will often

be necessary to resect this cicatricial tissue in such a manner that the graft is surrounded by living tissue, well disposed to receive its guest and to nourish it. We have several times failed in our attempt through having made this resection of cicatricial tissue badly and incompletely. Moreover, it is necessary that

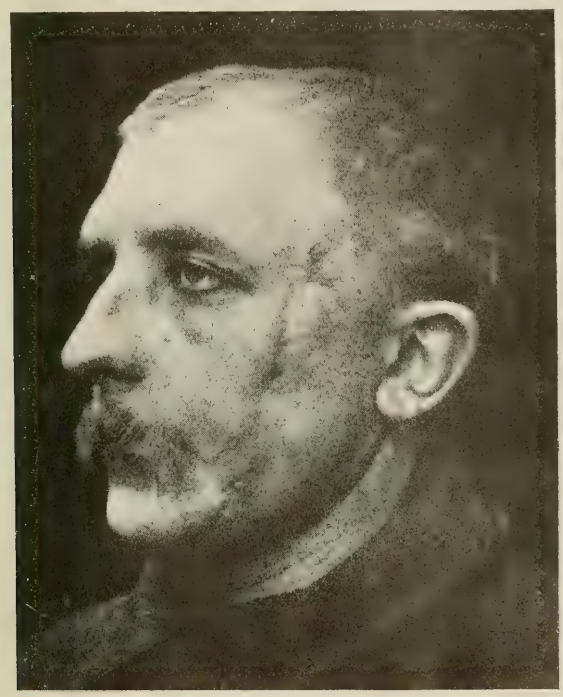


Fig. 71.

all bleeding should have been completely stopped by hydrogen peroxide; and especially by pressure with tampons, or at need by catgut ligatures, if torsion of the small vessel has not sufficed. If local anæsthesia be used, one must beware of solutions containing adrenalin which yield a provisional hæmostasis, followed by a reflux of blood and a small post-operative hæmorrhage. A graft surrounded by blood, even if it be aseptic blood, is not under good conditions.

Hence complete asepsis, good hæmostasis, the preparation of a bed free from cicatricial tissue, and a graft filling the cavity well, are the needful conditions for a good adipose graft.

It is in this manner that we have been able to obtain

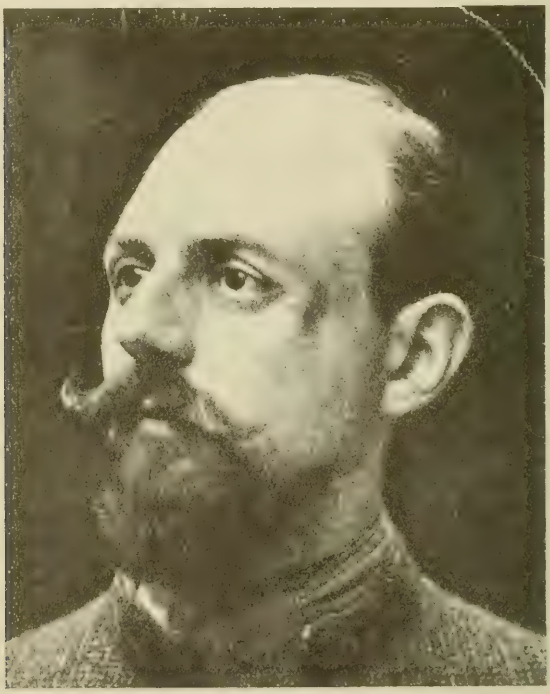


Fig. 72.

some good results, such as those shown in the Figs. 70 to 73, referring to Cases 59 and 60.

It may perhaps be remarked that these operative results leave something to be desired in the sense that there still persists a trace of the injury; that is due, first, to the circumstance that the photograph, which is very truthful, owing to not having been retouched, was taken before time had completed its work, and second, to the fact that our *poilus,* in a

hurry to "get through with it," refused the little complemental operations by the aid of which one could easily banish the vestiges still visible in Figs. 69, 71 and 73.

(3) *Cartilaginous Grafts.*—Transplantations of cartilage in reparative surgery were advocated by Von

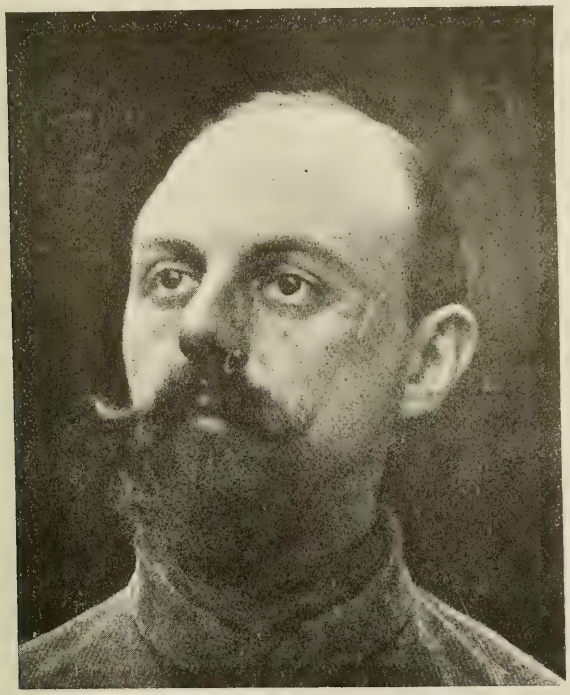


Fig. 73.

Mangold in 1903, and afterwards by Nélaton and Ombredanne, in the chapter "Autoplasties et Rhinoplasties" in the treatise by Hartmann and Berger. Mutilations of the face having become very frequent since the war, the method has been employed anew with success by Morestin. This surgeon had, since 1913, made several attempts at facial restoration by means of autoplastic cartilaginous transplantation; his

first papers on the subject date from May 7, 1913 and November 11, 1914, before the Société de Chirurgie de Paris. At the Congress of the International Society of Surgery of New York (April, 1914) MORESTIN was in charge of the report on grafts and transplantations in reparatory surgery. Since 1915, by the aid of numerous communications, he has perfected our knowledge of the technique of the operation, and has shown the brilliant results obtained, not only in building up the nose or the lower jaw, but also in the restoration of the orbital walls destroyed by injuries of war.

We shall review some of the publications of this master of autoplastic surgery.

MORESTIN reports the case of a soldier [1] who presented a curvilinear cicatrix at the lower part of the forehead above the left eyebrow; the superciliary arch, the orbital margin and the lower portion of the frontal bone between the orbit and the frontal prominence were wanting. A deep depression corresponded to this loss of bone substance over which cerebral pulsation could be seen and felt. In two preliminary operations MORESTIN removed the projectile which was found at the inferior part of the frontal sinus, then extirpated a fistulous track at the internal part of the frontal cicatrix.

Two months after recovery from this operation, the cicatrix was in turn removed, ligaments were loosened to prepare a bed for the graft, which was borrowed from another subject; the cartilage was shaped to the form of the superior orbital arch and the wound hermetically closed. The result was most satisfactory, as the photographs testify.

In a second article,[2] MORESTIN publishes two similar cases. A man, wounded by a bullet, presented at the

[1] MORESTIN. On the repair of loss of substance of the cranium, and particularly of the forehead, by means of transplantation of cartilage.—*Société de Chirurgie de Paris, February* 9, 1916.

[2] On the reconstitution of the malar bone and the orbital margin by means of transplantation of cartilage.—*Société de Chirurgie de Paris, March* 1, 1916.

level of the right cheekbone a very deep scar in the form of a star with four rays, closely adherent to the subjacent tissue. The depression corresponded to the prominence of the malar bone and the orbital margin. The sixth and seventh costal cartilages were removed, united one to the other; the thoracic wound was closed in layers by sutures. The orbito-malar cicatrix having been extirpated, the surrounding integuments were freely undermined. After having examined the gap in the bone, a large piece, almost identical in shape, was carved out of the cartilaginous block, reconstituting the malar bone and the orbital margin. As it lacked stability, MORESTIN fixed it by means of another fragment, the whole being sutured to the temporal muscle and covered by the superficial layers. The wound healed in a week and the result was æsthetically perfect. The second case was a soldier, bearing a very apparent deformity, resulting from the destruction of the external portion of the right inferior orbital margin and the anterior portion of the right malar bone. The bony portion was filled up by means of split cartilaginous fragments derived from another subject, placed with the epidermic surface turned towards the deep portion of the cavity. MORESTIN completed their modelling in the wound, to ensure that their adaptation should be as perfect as possible. Rapid healing in a few days. MORESTIN finishes his paper by saying: "These two cases show what one may expect from cartilaginous transplantation in this kind of deformity. The method which I have recommended provides a very simple solution to a problem of reparatory surgery which has hitherto remained unsolved."

On May 31, 1916,[1] two new cases were presented

[1] MORESTIN. (1) Reconstitution of the malar bone and the orbital margin by means of cartilaginous transplantation. (2) Loss of left eye; comminuted fracture of the superior maxilla, destruction of the orbital margin, operation for repair; cartilaginous grafts. (3) Reconstitution of the malar bone and the external half of the orbital margin by cartilaginous transplantation.—*Société de Chirurgie de Paris, May*, 1916.

by this author, with complete operative and æsthetic success. In these cases there was very extensive damage to the orbital walls with and without preservation of the eyeball. At the same meeting, MORESTIN showed a soldier for whom, on August 10, 1915, he had reconstituted the malar bone and the external half of the orbital margin by cartilaginous transplantation (about ten months before), a case which suggested to him the following reflections : " It appears to me that it is interesting to demonstrate, by this example, how one can, on the same subject, perform successive graftings of cartilage borrowed from himself or from others ; it is equally useful as showing the stability of the transplanted grafts. The cartilaginous mass has undergone no reduction in size during this lapse of time. I never lose an opportunity of insisting upon the stability of the results of cartilaginous grafts. That is an essential point, one of the fundamental reasons, which allow us to advocate this method in reparative surgery."

Speaking of another case, MORESTIN fully demonstrates his manner of procedure, and we cannot do better than summarise it

Amongst injuries of the face,[1] there is a type which one meets frequently. In it the eyelids are more or less torn through, the eyeball often injured, the malar bone and the external wall of the orbit carried away or destroyed over a large extent. The interrupted orbital margin is wanting in its infero-external portion, the integuments of the malar, temporal and mandibular regions participate in the deformity. There is an enormous bony depression, associated with shocking facial asymmetry and vicious position of the eyelids by reason of irregular and very extensive cicatrices.

In these cases, " Reparation has to be preceded by the excision and the gradual reduction of the cicatrices." It is best to proceed by two successive

[1] MORESTIN. Reconstitution of the malar bone and of the orbital margin by cartilaginous transplantation.—*Société de Chirurgie de Paris, August* 9, 1916.

operations. In the first place an autoplasty is made, having as its object the restoration of the destroyed integuments; after having liberated and brought the eyelids into good position and performed blepharorraphy, a flap is fashioned from the temple and the adjoining portion of the forehead, a flap whose pedicle must often be taken from behind because of the cicatrices which occupy the anterior part of the region. This flap is put in position and sutured.

After five or six weeks the restoration of the bony framework can be proceeded with. One of the cicatrices is reopened, the flap is detached with the neighbouring integuments, the conjunctival sac is put on one side, with the intra-orbital soft parts, avoiding, at all costs, the opening of the conjunctiva or the maxillary sinus. The boundaries of the loss of osseous substance are examined, the breach is prepared, the grafts, taken from the patient himself (the sixth and seventh costal cartilages), are trimmed to the size and shape required and installed in place. Finally the wound is hermetically sealed. It only remains, a few days later, to separate the eyelids and insert an artificial eye, if the globe has been destroyed by the injury or sacrificed by necessity.

With regard to this, it should be noted, adds Morestin, that in cases in which the eye is lost, it may be advisable during the course of the operation of grafting, to slip some fragments of cartilage into the interior of the orbit, so as to push forward the conjunctival sac and thus permit the wearing of an artificial eye under the best possible conditions.

After the account of the procedure employed and the results obtained by Morestin, whose methods seem to us particularly worthy of approval, we shall give an account of those we have used in our clinic during the same period as our colleague and often inspired by his counsel.

Two different conditions may present themselves: either the fractured orbit communicates with the neighbouring cavities, the maxillary sinus and the nasal

fossa, or the loss of substance affects only the orbital margin over a greater or less extent, without the adjoining cavities being implicated.

(*a*) *When the neighbouring cavities are in communication with the orbit*, it is needful in the first place to shut off this communication; should the maxillary sinus suppurate, it must be curetted, freely opened by the side of the nose, or if necessary a radical cure performed by the classic method. No surgical interference with the wall of the orbit is permissible until a complete result has been obtained on the side of the antrum. Moreover, it is unnecessary to hurry, deliberate operations are the best.

In a considerable number of cases the projectile, which has smashed up at the same time the floor of the orbit and the maxillary antrum, has spared the conjunctival mucous membrane; this torn mucous membrane, separated from its normal relations, is a great help in isolating the orbit from the neighbouring cavities; by dissecting it up in an appropriate manner, it can be drawn towards the opening, and sutured there, its deep surface against the neighbouring cavity. In this manner all communication with the nasal fossæ can be cut off. When the region of the lacrymal sac has been extensively destroyed, we have been able to obtain this result after several interventions; we could cite here several cases of this kind in which there has been great damage, opening up communications between the orbit, the nasal fossæ, and the antrum.

When the frontal sinus has been widely opened in front and on the orbital side, it is necessary to wait until suppuration has disappeared and a cicatrix has taken the place of the fleshy granulations; later, by an adipose or cartilaginous graft it will be possible, even easy, to fill up the cavity.

Hence, so long as the cavities adjoining the orbit communicate with it and suppurate, we must attend to them, to cure them in the first place so as to have to do with the orbit alone. Then we shall be in the con-

ditions realised at the outset by fractures which involve the orbital margins or the external surface, without communication with the neighbouring cavities.

(*b*) *When the orbit alone is fractured*, it is usually the region of the cheek-bone which bears the brunt of the traumatism. The malar bone is crushed and destroyed; in its place is a deep depression, the lower eyelid is torn to rags, and the eye usually carried away by the projectile or removed by the first surgeon who attends to the casualty. When the eye is preserved, it is often in a condition of enophthalmos because the floor of the orbit is sunk in towards the maxillary sinus, or because there is absorption of the cellulo-adipose cushion which supports the globe. The upper margin of the orbit is sometimes alone injured, and there exists in its place a large very unsightly hollow.

All these disfigurements can easily be repaired by cartilaginous grafts, and we cannot too strongly recommend to our colleagues the method initiated by Von Mangold, and admirably brought to perfection by Morestin.

We have acquired some experience in this method of surgical intervention, and we will place before our readers the results of our work, as well as the inevitable difficulties which we have encountered: the more because we performed the operations at the same period as Morestin, or a little later, before becoming well acquainted with our colleague's technique. We have therefore had to make, so far as concerns this subject, a personal apprenticeship.

Cartilaginous grafts are in truth a conquest of modern surgery; they are more useful, more readily affected, and more reparative than adipose grafts. Everything has been said by Morestin concerning the operative procedure, and we have intentionally quoted him fully above. We shall only add some details which will put our readers on their guard against certain mistakes which we have ourselves committed, and which will enable them to comprehend what we have to expect in this kind of operative interference.

In the first place we must emphasise that it is necessary to be resigned to successive operations. We have made the mistake of wishing to do too much at once. Some of our patients were eager to have finished with the business, and we allowed ourselves to be influenced by it in our surgical conduct. We

Fig. 74.

were not afraid to do, the same day, a large blepharoplasty with pedicle, an adipose graft and a cartilaginous graft; we have succeeded sometimes from all three points of view, and we have at this moment under our care a fortunate example; but we have failed several times, and we do not recommend this course of action. It is an error, in fact, to graft a piece of cartilage to take the place of the orbital margin, to

cover it with adipose tissue and to suture over the whole a raw flap. The flap destined to become an eyelid needs to rest upon a solid foundation, upon a tissue capable of giving it nourishment, not upon a graft which has need of receiving nourishment itself. It will be necessary, when dealing with such a case, to make

Fig. 75.

the patient understand that two operations are necessary. We commence at first with a blepharoplasty, and, six weeks later, we introduce under the skin the necessary cartilage and cellulo-adipose tissue. Figs. 74 and 75 are very instructive from this point of view; we attempted to do everything at once, with the result that the adipose graft has been eliminated.

The adipose graft is eliminated, but the cartilage

has held perfectly, and it is a detail to which I would particularly call attention; cartilage will easily live wherever it is put, it is content with aseptic surroundings and some interstitial liquids to penetrate it. It lives as a parasite, frugally, but it *does* live and remains as cartilage. It is quite remarkable to see it persist,

Fig. 76.

and maintain its position and its good appearance at the bottom of a cavity which has not been able to retain the fat with which we had filled it.

This demonstrates what one may expect from a graft of cartilage made aseptically, and introduced into its position by means of a button-hole which allows it to insinuate itself into the subcutaneous interstitial tissue to the desired depth. Cartilage

thus grafted always succeeds; MORESTIN has shown at the Société de Chirurgie cases which are relatively old; we can cite very instructive cases of a similar nature.

The illustrations above show some of our results. They would have been more complete if it had been possible for us to perform some small retouching

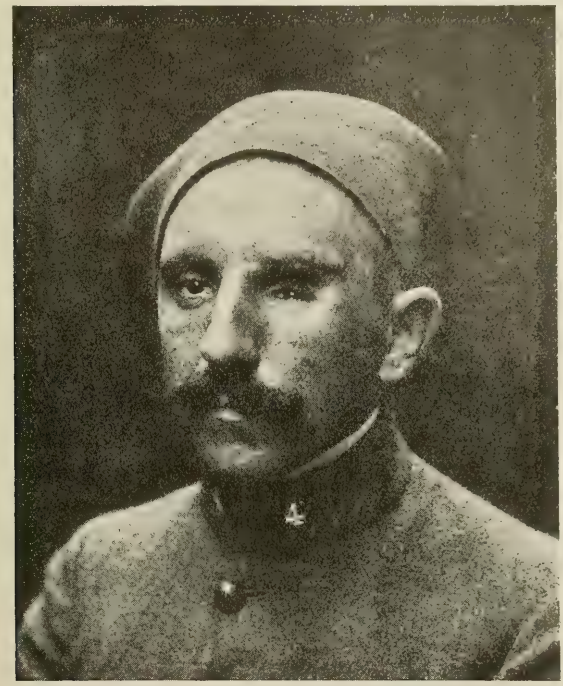


FIG. 77.

operations on the patients. Such as they are, however, Figs. 74 and 75, 76 and 77 show that the orbital arches can be restored. In the first case, the adipose tissue, grafted at the same time as the cartilage, was eliminated; in the second, the orbital arch has been completely re-established, the eye is not wide open because the subject was enophthalmic owing to depression of the orbital floor.

Moreover, it is quite easy to obtain the cartilaginous graft. Its dissection causes no inconvenience, immediate or remote; when aseptic the wound does not suppurate, and it is quite sufficient, in order to ensure that the thoraco-abdominal wall should also remain aseptic, that while the operator is finishing the orbital operation the assistant in charge of the thoracic wound should close the incision neatly, with catgut, in layers, with a muscular, an aponeurotic, and a cutaneous series of sutures.

We take up a fragment of cartilage a little larger than is required, and shape it at will, cutting it to give it the requisite form. The little fragments serve as packing for the principal piece; thus one builds up in the site of the orbital margin or the malar bone an edifice, like a wall, which will replace that which the projectile has destroyed.

Such are the principal reflections inspired by our experience of cartilaginous grafts, we are doing this kind of operation, more and more, and with increasing confidence; and, if we do not cite a large number of cases, it is because many of them are too recent to take their place in this work.

When, by reason of their long standing they merit to be published, we shall make them the subject of a special article.

## CONCLUSIONS

In conclusion, we wish to bring forward the original ideas developed in this work :

(1) We wish to call attention in the first place to this fact, that fractures of the cranium by projectiles of war, implicating the cranial vault, at a certain distance from the orbit, even when they are accompanied by large losses of substance and in consequence by well-marked concussion, do not give rise to either irradiation or fracture by contre-coup of the vault of the orbit. Contrary to what is taught in the classic literature, the sphenoidal fissure, the optic foramen, and the structures which pass through them remain unharmed after such traumatism.

In military surgery, fractures of the orbital vault are direct fractures.

(2) The eye is often involved in fractures of the orbit, even when neither the projectile nor bone fragments have directly touched it ; there are produced, at the macula or around it, concussion lesions, well-marked and very serious ; they can be seen by means of the ophthalmoscope in the form of hæmorrhages or lacerations, sometimes only choroidal, often choroido-retinal.

In addition to lesions visible to the ophthalmoscope we may note the disorders which cannot be seen. The central visual acuity of a subject, whose eye appears absolutely intact, may be very low ; these disorders may, further, up to a certain limit, be repaired, but their importance should be considered as of the first order by clinicians in the establishment of their diagnosis and in military medico-legal certificates. The affections described under the name of

"retinal concussion" are the first degree, the degree invisible to the ophthalmoscope, of these lesions due to concussion from a distance.

(3) Besides these concussion lesions we have, in this work, brought prominently forward the lesions of contact produced by a projectile which has grazed or slightly contused the eye while passing alongside it, or by an osseous fragment more or less violently projected towards the eyeball.

Concussion lesions and contact lesions often exist together; a minute ophthalmoscopic examination allows these varieties of lesions to be allotted their respective shares in the anatomical derangements undergone by the deep membranes.

(4) Between the production of these various disorders and the manner in which the projectile has injured the orbit, there exist relations so constant that we have been able to formulate the clinical data under the form of laws, the accuracy of which we are verifying every day, and to which we think we should draw the attention of our colleagues in a special manner (p.813 et seqq.).

(5) When the retina and choroid are much torn, there is produced, as the result of more or less abundant intra-ocular hæmorrhage, not the classic proliferating retinitis, but a choroido-retinitis presenting peculiar characters, which we have attempted to bring into prominent relief, and which cause this affection to be a morbid type, not hitherto described.

The cases, frequent in military surgery and rare in civil ophthalmology, of total avulsion of the optic nerve, produce this proliferating choroido-retinitis in maximum degree.

(6) One detail which has impressed us, amongst our patients, is the absence of partial scleral ruptures produced according to the theory of the equator of depression. The projectiles which strike the eye tangentially cause lesions of contact; if they contuse the eye with sufficient directness to break its fibrous framework, they smash it completely and destroy

it; there is no place in military ophthalmology for ruptures of the sclerotic in the intercalary region and subconjunctival luxations of the lens, etc. . . . Projectiles which strike the eye directly penetrate its interior if they are small; if they are large they destroy it, the organ is entirely disorganised.

After thirty months of practice and seeing more than six hundred fractures of the orbit, we have not seen a single case which departs from this rule; doubtless exceptions may be met with, but the clinical verity, which we lay down here, remains on a basis none the less solid.

(7) We have further, by means of our cases, been able to make a special study of hæmatomata of the sheaths of the optic nerve, and we are confident that the hæmorrhage does not spread along them into the ocular cavity, as the best authorities have taught; but that the hæmatic pigment, after a rather long period of time, diffuses as far as the disc, and produces a pigmented crescent or ring, the direct consequence of the hæmorrhage. There is not propagation to the papilla of a recent hæmorrhage into the sheaths of the nerve; but there is, secondarily, somewhat slowly, migration of the hæmatic pigment.

(8) So far as therapeutics are concerned, this work contains information upon reparative surgery of the orbit by means of adipose and cartilaginous grafts, to which we consider it our duty to call the attention of ophthalmologists, whose place it is to maintain the surgery of the orbit abreast of progress of every kind.

# LIST OF CASE-REPORTS


1. Fracture of right orbit by rifle bullet, 814–15
2. Fracture of superior wall of left orbit and frontal sinus by shell fragment, 816
3. Fracture of right superior orbital margin with atrophy of optic nerve, 817
4. Fracture of both orbits by bullets, 817–18
5. Fracture of both orbits, with hæmorrhage into vitreous body, R. E., and macular choroiditis, L. E., 818–19
6. Bullet traversing face, bilateral macular hæmorrhage, 820–1
7. Fracture of right orbit, laceration of choroid, optic atrophy, R. E., 821–2
8. Wound of facial bones, macular and peripheral choroido-retinitis, R. E., 822–4
9. Fracture of external wall of right orbit; macular choroido-retinitis; avulsion of optic nerve, 824
10. Fracture of external wall of left orbit, choroido-retinitis, L. E., 825
11. Fracture of left orbit, section of optic nerve, neuro-paralytic keratitis, 825–7
12. Fracture of both orbits, retinal hæmorrhage, R. E., detachment of choiroid, L. E., detachment of retina, R. E., 827–9
13. Fractures of both orbits, retinal hæmorrhage, R. E., retinitis proliferans, L. E., 829–30
14. Fracture of right orbit, rupture choroid, R. E., 830–1
15. Fracture of floors of both orbits; double retinal detachment; macular lesion by concussion, 832–3
16. Fracture of left orbit, detachment of retina, L. E., 833–4
17. Bullet wound of face; fracture of left inferior orbital margin; detachment of retina, L. E., 834–5
18. Fracture of left orbit, rupture of choroid, 836–7
19. Fracture of right orbit; foreign body; macular choroido-retinitis, 837–9
20. Fracture of superior-external margin of right orbit; foreign body; choroido-retinitis, R. E., 839–41
21. Fracture of left orbit; foreign body; optic atrophy and choroido-retinitis, 841–2
22. Fracture of left orbit; optic atrophy, 843–4
23. Fracture of right orbit; foreign body; extraction by Kronlein's method, 844–6
24. Fracture of external wall of left orbit; foreign body; retinal detachment, 846–8
25. Fracture of left orbit; foreign body; macular choroiditis, 848–9
26. Fracture of left orbit; total ophthalmoplegia; optic atrophy, L. E., 857–9
27. Fracture of right superior orbital margin; hæmorrhage into sheaths of optic nerve, 868–9
28. Fracture of left orbit, right macular choroido-retinitis, 869–70
29. Fall on head from shell explosion; indirect lesion of optic nerve; hæmatoma of sheath, 870–1
30. Wound of right temporal fossa, detachment of retina, R. E., 899–900
31. Perforating wound of right temporal fossa, rupture of choroid, R. E., 900
32. Contusion of left orbital margin, rupture of choroid, L. E., 900–1
33. Traumatism of malar region; optic neuritis; rupture of choroid, R. E., 901
34. Perforating wound of right orbit, rupture of choroid, R. E., 902
35. Bullet wound traversing malar bones and nasal fossæ; choroido-retinitis, L. E., 902–3

36. Traumatism of the malar region; rupture of choroid, retinitis proliferans, L. E., 903
37. Traumatism of bones of face; rupture of choroid, L. E., 903
38. Progressive myopia; macular choroido-retinitis, R. E., 904–5
39. Section of sympathetic; enophthalmos; Claude Bernard's syndrome; recovery, 921–2
40. Fracture of right orbit; enophthalmos consecutive upon trophic troubles, 925
41. Contusion of left orbital region, probably fracture; traumatic enophthalmos, L. E.; trophic troubles, 925–7
42. Paralysis of external rectus and consecutive trophic troubles, 927–8
43. Fracture of left orbit; foreign body in right orbit; atrophic and pigmentary choroido-retinitis, 929–31
44. Fracture of left orbit; traumatic enophthalmos; total detachment of retina, 931–33
45. Post-traumatic enophthalmos; depression of external orbital wall and inferior orbital margin, 933–4
46. Fracture of left orbit; rupture of eyeball; arterio-venous aneurism of left internal carotid, 938–9
47. Fracture of left orbit; rupture of eyeball, 940
48. Fracture of right orbit; rupture of right eyeball; traumatic choroido-retinitis and optic atrophy, L. E., 940–1
49. Fracture of right orbit; rupture of eyeball, 941–2
50. Wound of left temporo-orbital region; fracture of external wall of orbit; rupture of eyeball; foreign body in orbit, 943–4
51. Fracture of right orbit; rupture of eyeball; foreign body, 944–5
52. Foreign body irritating optic nerve; sympathetic ophthalmia, 945–6
53. Fracture of floor of left orbit; crushing of eyeball, 949-51.
54. Fracture of left orbit and left maxillary sinus; rupture of left eyeball, 951
55. Fracture of right orbit and frontal sinus; destruction of eyelids and right eyeball; voluminous foreign body in left maxillary antrum, 951–2
56. Fracture of internal wall of left orbit; destruction of nasal wall and antrum; rupture of eyeball, burying of eye in antrum, 953
57. Fracture of floor of right orbit; cicatricial ectropion; choroido-retinitis; foreign body in antrum, 954
58. Fracture of supero-internal orbital wall; opening of left frontal sinus, 956
59. Fracture of facial bones, frontal sinus and ethmoid; adipose graft, 957–8
60. Fracture of left fronto-orbital region involving frontal sinus; hæmorrhage into vitreous body; adipose graft, 958
61. Fracture of left orbit; retrobulbar neuritis, L. E., 960–2
62. Fracture of left orbital vault; perforation of globe; total detachment of retina, 962–63
63. Fracture of apex of left orbit; bilateral papillary stasis; "mal comitial," 963–4
64. Fracture of left orbital region involving vault; loss of cerebral substance; contusion of globe; hæmorrhage into the vitreous body, 964–5
65. Fracture of right orbit; rupture of left eyeball; cerebral abscess; recovery, 965–6
66. Smash of orbital vault; rupture of eyeball; intra-orbital meningo-encephalocele; 966–7

# INDEX


Abnormal mobility, determination of, in fractures of mandible, 633 *et seq.*
Abscess, sub-dural, under frontal lobe, 965–966, 968.
Acetozone, 93–94.
Active movements, in after treatment, 157 *et seq.*
Acuity, visual, 1014–1015.
Adipose grafts, 932, 940, 958, 997–1003.
Ætiology of fractures of the orbit, 802–806.
Affections of visual apparatus, laws governing, in injuries of orbit, 813 *et seq.*
Air passages, clearing of, in dyspnœa, 630.
Albucasis on orbital lesions, 778.
Alquier's appliance, 420, 539.
Ambulance cases seen, figures, 5.
Amnesia, 963.
Amputation, 10.
Amputation and esquillectomy, choice between, 340.
  at knee, 214–215.
  indications for, 13, 15, 17, 229.
  of foot, 244, 260.
  of thigh, consequent on wounds of knee, 204.
  total of hand, 173.
Anærobes, living, introduction of, (Donaldson's method), 100.
Anatomical features:
  of fracture of neck of humerus, 385.
    sub-deltoid fracture, 400.
    shaft of humerus, 406.
    supra-condylar fracture, 433.
  of fractures of forearm, above elbow joint, 441.
    shaft, 446.
  of fractures just above wrist, 460.
Anatomical features:
  of fracture of shaft of radius, 465.
  of fracture of lower radial epiphysis, 476.
  of fractures of femur, subtrochanteric, 494.
    shaft, 507.
    supra-condylar, 547.
  of fractures of leg, shafts, 554.
  of supra-malleolar fractures, 569.
Anchorage of fragments of jaw, debatable question, 713.
Anesthesia, 343.
  cutaneous, with fracture of mandible, 638–639.
  in fractures of jaw, 740–741.
Anesthetic, choice of, in fractures of mandible, 741.
Aneurism, arterio-venous, accompanying orbital lesion, 939, 942.
  cause of, 874.
Angle's apparatus for paramedian fracture of jaw, 683.
Angle's arch, 663.
  adjustment of, 665.
Ankle, wounds and fractures of, 234 *et seq.*
Ankle wounds, types of, 237.
Ankylosis, and sinuses, 169.
  avoidance of, 32.
  of jaw, permanent, 649.
  production of, 31.
  vicious, 254.
"Anse calcanéenne," 243.
Anterior fractures of mandible, 599, 676.
Anterior Tarsus, resection of, 258.
Apparatus, fitting of in fracture of thigh, 532
  for expansion of mandible, 685.
  for reducing fracture of ramus of jaw, 708.
  supporting, after resection, 32.

Arlt's theory of the equator of depression, 891–896.
Arthrodesis, radio-ulnar, 476.
Arthrotomy, 16.
in elbow wounds, 134 *et seq.*
in joint wounds, 10.
indications for, 13.
supporting apparatus, after, 32.
Articular comminuted fractures, 7.
Articular fractures, types of, 6, 9.
Artificial dilatation of socket, for prosthetic purposes, 996.
Artificial eye, 939–942, 944–945, 951–952, 965.
preparation of orbit for, 995.
leg, sometimes preferable, 16.
teeth and plate, 659 *et seq.*
Asepsis, in shoulder wounds, 107.
Asphyxia, caused by descent of tongue into pharynx, 663.
Assessment of disablements, by fracture of mandible, 763.
Astragalectomy, after treatment, 248.
Astragalus, fractures of, 241.
Asymmetry, facial, characteristics of, 638.
Atrophy of the eye, 926, 941.
Aura, sensory, 963, 968.
Autopyovaccine, 99.
Avulsion of the optic nerve, 811–812, 826, 860–861.

B. ærogenes capsulatus, cause of gas gangrene, 299.
Bacteria concerned in infected fractures, 295.
Bacteriologic control of wound, Carrel-Dakin method, 50.
Base hospitals, cases seen at, 4.
"Bayonet leg," 574.
Berlin's diagnosis of seat of orbital fracture, 781, 782, 972.
Bernard, Claude, syndrome of, 921.
Bertherand on "Gunshot wounds of the orbit," 779–780.
Bipp (bismuth iodoform paraffin paste), 77.
employment of, 77 *et seq.*
Rutherford Morrison's Method, 77.
Blake's splint, 522.
Blepharoplasty, 939, 941–942, 950–954, 993–996, 1011.
Blood-vessels, lesions of the, 872–879. *See* Aneurism, Hæmorrhage, etc.
Bone, division of, 24.
marrow, affected, 301.
death of, 302.
infection of, 12.
restoration of, 997-1014.
substance, large loss of, in fractures of mandible, 622 *et seq.*
treatment of, 345.
Bones of orbital cavity, 789 *et seq.*
Bonnet, principles of, 364, 368.
Bony and cartilaginous grafts, results, in fractures of mandible, 757 *et seq.*
Bony graft from still-born infant, 761.
in treatment of wounds of jaw, 735.
Bony surfaces, occlusion of, 27.
Bony union, 27.
Boot, with lateral supports, 32.
Bosquette's pelvi-pedial support, 525.
"Bouche du chantre de village," 654 *et seq.*
Bracelet, leather, for support, 32.
Bracketed appliance, 396.
Brain, foreign bodies in, fracture of orbit, recovery, 968.
injury to, 959-960, 963, 965, 977, 979.
Bridge, method for anchoring fragments of jaw, 713.
removable, 662.
Brilliant green, 35.
paste, 83–84–85.
Bullet, carried 18 years in frontal sinus, 811.
Bullet extractor, early, 778.
Bullet wounds, long range, signs of, 279.
of joints, 7.
Bullets, conditions of wounds made by, 7.
Bursa, interosseaous, serous, 21.

Callus, formation, 352, 474.
healthy, essential for fracture union, 294.
moulding of, 326.
pathological, 336.
Capsule, rupture of, 884–885.
Capsulo-periosteal sheath, preservation of, 20.
Carrel's apparatus, modifications of, 57.
Carrel's distributing tubes, 44.

Carrel-Dakin method, 34 *et seq.*
advantages of, 38, 39.
bacteriologic control of wound, 50 *et seq.*
employment of, in various types of wounds, 47.
closure of wound after, 52.
instillation of, 46.
modification of, by Dimond and McQueen, 57.
rules for application of, 54 *et seq.*
technical precautions, 47, 48.
Carrel-Dakin solution, strength of, 39.
Carron du Villars on exophthalmos, 872.
Cartilage, unmouldability of, 27.
Cartilaginous grafts, 932, 947, 1003, 1014.
Cataract, after contusion of eyeball, 883.
Cataracts, traumatic, 882–885, 985, 988–990.
operation on, 988.
Cavalié's dictum on treatment of fractured mandible, 670.
Cavalié's technique in bone grafting, 756–757.
Cellulitis, 877–878.
Cerebral substances, loss of, by fractures, 959–960, 963, 965, 977, 979.
Cervical sympathetic, section of the, 921–924.
Chauvel on orbital fractures, 783–784.
Chloramin paste, application of, 63.
preparation of, 63.
Chloramin solution, preparation of, 62.
Chlorinated eucalyptol, preparation of, 60.
Chlorinated paraffin oil, preparation of, 60.
"Choked disc," 964.
Chopart's operation, 261.
Choroid lesions, 852, 891 *et seq.*
clinical laws relating to, 905.
laceration by concussion, 831.
by laceration and contusion, 828–829.
localisation of injury, 908.
mixed lesions, 907.
rupture by contusion, 900–904.
rupture by grazing, 853.
various causes and kinds of lesions, 891–899.
Choroidal hæmorrhages and detachment, 909.
Choroidal rupture, 892-894.
indirect 896 *et seq.*,
Choroido-retinitis, a lesion characteristic of present war, 1016.
morbid type of, 1016.
ophthalmoscopic appearance in, 912.
traumatic, proliferating, 910 *et seq.*
Cleansing, immediate, essential in treatment of fractures, 314.
Clinical course in:
fracture of humerus, neck of, 378.
shaft of humerus, 408.
subdeltoid fracture, 401.
supracondylar fracture, 434.
fractures of forearm above elbow joint, 442.
just above wrist, 461.
shaft, 448,
fracture of shaft of radius, 466.
lower radial epiphysis, 477.
fracture of ulna, 485.
fractures of femur, shaft, 510.
subtrochanteric, 495.
supracondylar, 548.
fractures of leg, shafts, 555.
supramalleolar fractures, 570.
Closure of jaws, 646.
indemnity for, 771.
Clothing particles, carried by projectile, 1.
Collargol, use of, in wounds, 76.
"Colmatage," 991.
Colon, rupture of, 187.
Commissural nerve, 794.
Complete mandibular fractures, 602-603.
Complications of the eye, 970-992.
Conclusions in regard to the eye, 1015-1015.
Concussion lesions of eye, 1015.
Conjunctival *culs de sac*, restoration of, 994-996.
Consolidation, 409.
delayed, 383.
Contact lesions of eye, 1016.
Contamination of wounds, extirpation of, 36.
Contusions of the globe, 852-853, 882-885.

Correction of deformity of jaw, mechanical means for, 672.
Cranial bones, origin of, 793.
Cranial cavities, lesions of, with orbital fractures, 959.
fractures, 807-810.
Cranium, vertebral theory of the, 793.
"Crank" devised by Villain, mechanism of, in fracture of jaw, 718-719.
"Cranks," types of, 720.
Crushing of limb, 6.
Curetting, essential, 348.
Cutaneous anesthesia, 638-639.
Cyst, meningeal, 947, 949.

Dakin solution, alkalinity, Lyle's test for, 42.
apparatus for, 43
with boric acid, 41.
without boric acid, 40.
Damage to face, by fracture of mandible, 630.
Death, after fracture of orbit, 781.
"Débridement," 297.
Delagenière's method of bone graft, 757.
Delbet's apparatus, 356, 417, 538, 564.
Delbet's pyoculture method, 35, 36, 94-95.
Delens, on fractures of the orbit, 784.
Delorme on orbital fractures, 786, 810.
on removal of splinters, 971.
Demarquay on orbital effusions, 873.
on orbital wounds, 780-781.
De Monacho on orbital fractures, 787.
Dental adjustment, normal, 587.
Descent of tongue into pharynx, 663.
Destruction of eyeball, and neighboring cavities, 946 *et seq.*
"Detache-tendon" of Ollier, 23.
Detachment of choroid, 905-906.
of retina. *See* Retina.
De Weeker on choroidal lesions, 898.
on effects of hæmorrhage, 865-867.
on orbital fractures, 782.
on orbital hæmorrhage, 869.
on treatment of fractures, 971.
Dialysis of iris, 887-890.
Dichloramin-T, 35.
employment of, 61.
in oil method, 58, 62.
method of preparing, 59.
Diplopia, 844-846, 931, 933, 956.
Direct fractures of orbit, 806.
Disablements, assessment of, in fractures of mandible, 763 *et seq.*
Disinfection, of open fractures, 314 *et seq.*
of soft parts, 343.
Displacement, 290.
lateral, 311.
various types of, 312.
Distributing tubes, Carrel's, 44.
Division of one, 24.
Donaldson's method, 100.
Drainage, 27.
by esquillectomy, 334.
Drapier's apparatus, as substitute for humerus, 274.
Dressings, 414.
bad practices, 29.
in fracture of thigh, 534 *et seq.*
of joint wounds, 28.
over voluminous, 29.
points in, 349.
suitable time for, 29.
Duchange's apparatus for expansion of mandible, 687.
Dupuy-Dutemps on hæmatoma, 866-867.
Dupuytren, on orbital fractures, 780.
on wounds of the orbit (1854), 780.
Dynamics, laws of, applied to orbit, 797.
of the orbit, 797–801.
Dyspnœa, 112.

Early treatment, indications for, in:
fracture of the humerus, neck, 389.
middle of shaft, 411.
sub-deltoid fracture, 402.
supracondylar fracture, 434.
fractures of forearm, above elbow joint, 444.
just above wrist, 461.
shaft, 450.
fracture of shaft of radius, 468.
of lower radial epiphysis, 479.
fracture of ulna, 487.

Early treatment, indications for, fractures of femur, subtrochanteric, 496.
shaft, 512.
supracondylar, 548.
fractures of leg, shafts, 556.
supramalleolar fractures, 571.
Ecchymosis of the conjunctiva, 875–876, 903.
Ectropion, cicatricial, 954.
Effusion from base of cranium, 798.
intra-orbital, 872–879.
Elbow, wounds and fractures of, 129 *et seq.*
after treatment, 155 *et seq.*
evacuation of patients with, 160.
late after treatment, 162 *et seq.*
operative technic in, 149 *et seq.*
profuse suppuration in later cases, 164–165.
types of, 131.
Electro-magnet, use of, 981.
*Encyclopédie francaise d'Ophtalmologie*, 786.
Endothelial cells of synovial membrane, 20.
Enophthalmos, 849–850, 917–921, 921–925, 926–937.
false and true, 928–929.
nervous theory of, 923.
symptoms and diagnosis, 934 *et seq.*
traumatic, 917, 931, 937 *et seq.*
treatment of, 937.
Enucleation, cases of, 933, 939–943, 945–950, 954–955, 965, 976–977, 984–985, 987.
early practice of, 781.
of eye, 976.
Epileptiform attacks, accompanying fracture of orbit with neuritis, 979.
Epiphyses, fractures of, 25.
Epithelial lesions, superficial, of eyeball, 882.
Equator of depression in rupture of choroid, 791–796.
Esquillectomy, 10, 412.
advantages of, 316–317 *et seq.*
and amputation, choice between, 340.
counter-indications to, 339.
criticisms of, 319.
details of, 345.
in hip wounds, 188.
in shoulder wounds, 106.
Esquillectomy, in wrist wounds, 172.
indications for, 14, 331.
predisposing to pseudarthoris, disproved, 322.
prophylactic, 315.
sub-periosteal, 328 *et seq.*
Ether or chloroform, choice of, for operations on fractured jaws, 741
Ethmoiditis, 887.
Eusol and Eupad, 67 *et seq.*
Evacuation of patients after:
shoulder wounds, 124.
elbow wounds, 160.
wrist wounds, 180.
hip wounds, 197.
knee wounds, 225.
ankle wounds, 252.
foot wounds, 268.
Evisceration, 976.
Exophthalmos, 837, 839, 841–842, 858.
consecutive, 872, 875–879, 920–921, 965.
reduction of, 975.
Expulsive hæmorrhage, 905–906.
Extension, by metallic loop, 359.
by sliding appliances, 360.
choice of position for, in fracture of thigh, 530–531.
continuous, by weights, 357.
in fractures of the femur, 519 *et seq.*
methods of effecting, 423.
Exterior orbital margin and wall, fractures of, treatment, 974.
External wall of orbit, fractures of, 811–812, 974.
Extravasation, intra-orbital, 774–775.
Extrinsic and intrinsic muscles, lesions of, 879–882.
Eye, concussion lesions of, 1015.
conclusions in regard to, 1015.
destruction of, 938–969.
and neighboring cavities, 946.
in fractures of orbit, 938, 975.
enucleation of, 976.
lesions of the, 882–899. *See also* Case Reports.
preservation of the, 813–827.
in orbital fracture, 813, 974.
ruptured, treatment of, 983.
Eyelids, restoration of the, 942, 993–996.

Facial asymmetry, after fracture of mandible, 637.
Facial bones, fractures of the, 957,
Fall, loss of vision after, 864.
Fatal results, rare, in wounds of face, 586.
Faulty union, 310.
Femur, fractures of the, 494.
fractures of shaft of, 507.
separation of head of, 185.
Ferrier's cachets, 675.
Fingers, amputation of, 474.
Finochietto's stirrup, 359.
Fissures, of orbit, 809, 810.
occurring in fractures, 284.
Fistula, 901.
Fixation apparatus, types of, 382.
by suspension, 379.
in fractures of the femur, 517.
Flail arm, 399.
Flail-elbow, 167.
Flail-like limb, after shoulder wounds, 128.
Flavine, (acri- and pro-flavine), 80 *et seq.*
Flavine and Bipp, 35.
Foot, amputation of, 244.
malposition of, 533.
solidity of, preserved, 243-244.
wounds and fractures of, 255.
Foramen, optic, fracture of the, 809.
the supra-orbital, 790,
Forcible reduction, 568.
Forearm, fractures of, 439 *et seq.*
Foreign bodies in antrum, necessity of extraction of, 980.
in the brain, 963, 965-968, 970, 977-978.
in the eye, 983, 986-987.
in orbit, removal of, 980-982.
various writers on, 780 *et seq.*
not necessary always to remove, 980.
removal of, essential, 315.
Fossa, right temporal, wounds of, 899-900.
Fossæ, nasal, fractures and wounds of the, 788, 902.
Fractures and wounds, of ankle, 234 *et seq.*
of elbow, 129 *et seq.*
of foot, 255.
of hip, 184 *et seq.*
Fractures and wounds, of knee, 201 *et seq.*
of the shoulder, 102 *et seq.*
of wrist, 170 *et seq.*
Fractures, as regards operative interference, age in, 737.
by contre coup does not exist, 1015.
as sepsis first essential in treatment of, 314.
"by contact," 597.
comminuted, articular, 7.
caused by other projectiles than long range bullets, 277.
chief types of, 281.
compound, treatment of, 8.
conservative treatment of, general principles, 313 *et seq.*
disinfection of, 314 *et seq.*
gunshot, reduction of, 353 *et seq.*
immediate results of, 292 *et seq.*
immobilization of, 362 *et seq.*
implicating cavities neighboring upon the orbit, 946-948, 976-980.
infected, 278, 294, 297, 304-305, 308-309.
bacteria concerned in, 295.
involving joints, 1 *et seq.*
of astragulus, 241.
of elbow, types of, 131-132.
of femur, 205, 494 *et seq.*
shaft of, 507.
of fibula, head and neck, 577.
shaft, 578.
types, 577.
of the forearm, 439 *et seq.*
essential points in anatomy, 440.
types, 441.
of humerus, 385 *et seq.*
complicated, 111.
shaft of, 406.
neck of, clinical course, 387.
physiological features of, 386.
types, 385.
of joints, resection of, 12.
of leg, 554 *et seq.*
shaft, appliances for, 560 *et seq.*
types, 554.
of lower limb, multiple, 581.
of malleolus, 579.
of mandible, alveolar border, 601.
anterior, 676 *et seq.*
anterior, old, 682.

Fractures, of mandible, at angle of jaw, 616, 641.
mechanical treatment, 703.
at ramus, 617, 642, 706.
closure of jaws, 646.
due to ankylosis, 648.
complete, 602-603.
complete, anterior, 603.
complete, lateral, 609 *et seq.*
complications of, 663-664.
coronoid process, 601.
diet suitable for, 676.
double and multiple, 620 *et seq.*
etiology of, 597.
expansion apparatus, 685.
facial asymmetry, 637.
incomplete, 600.
indemnity for, 767 *et seq.*
inferior border, 601.
intermaxillary anchorage, 689.
medium, anterior, immobilization of, 681.
old, 640-641.
operative technic, 736 *et seq.*
periods of treatment, 670.
preparatory treatment, 675.
radiography in, 644.
recent, 633 *et seq.*
stages of treatment, 629.
temporo - mandibular joint, 601.
time for operation, 758.
types, 599 *et seq.*
usually compound, 624.
of orbit, 777 *et seq.*
accompanied by destruction of neighboring cavities, 946 *et seq.*
complications, treatment of, 970 *et seq.*
direct, 806.
eye preserved, no retention of foreign body, 813–837.
foreign body retained, 837 *et seq.*
general considerations, upon, 802 *et seq.*
historical view, 777 *et seq.*
implicating neighboring cavities, 976 *et seq.*
indirect, 804.
intracranial complications, 979.
pathogenesis, 807 *et seq.*
reparative surgery in, 993 *et seq.*
Fractures, of orbit some recent writers on, 785.
statistics, 783.
statistics, in present war, 802 *et seq.*
with destruction of eyeball, 938 *et seq.*
with preservation of eyeball, 813.
without injury to optic nerve, 805.
of patella, 205.
of posterior tarsus, 243.
of radius, 465.
of shaft, general study, 277 *et seq.*
of tibia, 205, 574.
extra articular, 574–575.
lower end, 576.
shaft, 575.
of trochanter, 186.
of ulna, 484 *et seq.*
of upper limb, multiple, 490 *et seq.*
operative technic outlined, 316.
parietal, excision of, 11.
pathological anatomy of, 280 *et seq.*
pathological changes following, 294, 297, 304–305, 308–309, 397 *et seq*, 406, 458, 574.
produced by long-range bullets, 277.
supra-condylar, 433.
supra-malleolar, 569 *et seq.*
time of operation for, 333 *et seq.*
treatment of, 1 *et seq.*, 277 *et seq.*
essential points of, 313, 314.
with large loss of bony substance, 622 *et seq.*
Fragments, types of, 283.
Frontal sinus, lesions of, with orbital fractures, 956, 959, 980.
Function, recovery of, essentials for, 22.
Functional result, aim of operation, 142.

Galezowski on orbital fractures, 782.
Gas gangrene, 298 *et seq.*
does not accompany wound of face, 632.
Gastrostomy not indicated, in fractures of mandible, 666.
Gigli's saw, use of, 24.

Globe of eye preserved, 814.
Gonin on hæmatoma, 866–867.
Grafts, 932, 940, 947, 952, 995, 997–1014.
bony, results, in fracture of mandible, 751 *et seq.*
Guyon's supra-malleolar amputation, 261.

Hæmarthrosis with wounds of knee, 7.
Hæmatic pigment, diffusion of, 1017.
Hæmatoma of the sheaths of the optic nerve, 865–871.
in the newborn, 874.
theory of, 1017.
Hæmianopia, 804–805.
Hæmorrhage, by contre coup, 875.
choroidal, 905–906.
into optic nerve, 866–867.
intra-orbital, 872–879.
macular, 820–821, 839, 862, 870–871.
retinal, 870.
secondary, complicating lesions of jaw, 663.
secondary, grave symptom in fracture of mandible, 632.
traumatic into orbit, 872 *et seq.*
Hæmostasis, essential, 349.
Hand, total amputation of, 173.
Hawley's extension apparatus, 522.
Healing wound, with Carrel-Dakin method, 50.
Heliotherapy, 90, 157.
action of, 351.
marvellous results, 29.
Hennequin's sling, 521.
Hey's brilliant green, 35.
Hey Groves apparatus, 523.
Hip, wounds and fractures of, 184 *et seq.*
Hip wounds, operative technic, 190 *et seq.*
patients seen late, 199–200.
post operative treatment, 193.
Hippocrates, on foreign bodies in the orbit, 777.
on fractures of the internal margin and wall, 973.
Hirtz's compasses, 13.
History of orbital fracture, 777–788.
Homer on orbital fracture, 777.
Humerus, fractures of, 385 *et seq.*
fractures of the neck, 385.
fracture of shaft, 406.
fractures of, complicated, 111.
types of injuries of, 115.
Hydrostatic pressure, cause of fracture of orbit, not proven, 807.
Hygroma, formation of, 21.
Hypertonic solutions, 71 *et seq.*
Hypochlorite solutions, employment of, 45.
objections to, 58.
Hypochlorites, 35.
Hypochlorous acid preparations, Eusol and Eupad, 67.

Immobilisation, 417.
apparatus for lateral fracture of mandible, 700.
ideal, 365.
limited, 378.
of fractures, 362.
of jaw, easy, 593.
of jaws in occlusion, 705.
of joints, 28.
principles governing, 364.
subsequent treatment, 384.
"Incomplete" mandibular fractures, types, 601–602.
Indemnity for loss of teeth, 765.
Indirect fractures, of orbit, 804.
theory of, 807–812.
Inferior dental nerve, section of, 639.
Inferior orbital margin and wall, fractures of, treatment, 973.
Inflammatory complications, 889–890.
Injury, to brain, accompanying fracture of orbit, 785.
to eye, according to direction of projectile, 813–814.
in middle ages, 778.
to soft parts, accompanying fractures, 288 *et seq.*
Insolation, effects of, 30.
Intermaxillary anchorage, method of, 689.
Internal orbital margin and wall, fractures of, treatment, 973.
Intra-cerebral foreign bodies, with fracture of orbit, recovery, 968.
Intra-cranial complications of orbital fractures, 979.
Intrinsic muscles, lesions of, 879 882.
Inversion of the iris, 890–891.
Iodated starch, 80.
Iridio-capsulotomy, 989.
Irido-chorioiditis, 962.

Iris, injuries of, 887 *et seq.*
with hæmorrhage, 889.
Iritis of the aged, 889, 890.

Jaboulay's arthrotomy, 207.
Jaboulay's method of drainage of supra-patellar pouch, 210.
Javelle water, in treatment of war wounds, 65.
preparation of, 66.
Joint fractures, resection of, 12.
Joint infection, types of, 2 *et seq.*
with toxic symptoms, 3.
Joint, new, development of, 21.
Joint wounds, evacuation of patients, 33.
gravity of, 1, 4.
uncomplicated, 2.
Jointed splint, 529.
Joints, immobilisation of, 28.
wounds of, 1 *et seq.*
"Jumping the bite," 593.

Keratitis, 827, 840.
Kernig's sign, 877, 977.
Knee, joint lesions, types of, 208 *et seq.*
late pathological conditions of, 229 *et seq.*
wounds, and fractures of, 201 *et seq.*
Krönlein's operation for removal of foreign body from eye, 838, 840, 845, 981, 982.

Laceration of nerves and muscles, 852.
Lacrymal fossæ, 791.
Lambotte plate, 546.
Landolt on orbital fractures, 782.
Larrey, observations of (1832), 779.
Late pathological conditions of ankle, 253.
elbow, 164.
foot, 269.
hip, 199.
knee, 226.
shoulder, 126.
wrist, 183.
Late stages and results of:
fracture of humerus, neck of, 393 *et seq.*
sub-deltoid fracture, 406.
fracture of, shaft of, humerus, 429 *et seq.*
supracondylar fracture, 437.
fracture of forearm, above elbow joint, 445.
shaft, 456.
fracture just above wrist, 463.
Late stages and result of: fractures of shaft of radius, 473.
fracture of lower radial epiphysis, 481.
fracture of ulna, 488.
fracture of femur, sub-trochanteric, 504.
shaft, 541.
supracondylar, 551.
fracture of leg, shafts, 564.
of supramalleolar fractures, 573
Laws governing the affections of the visual apparatus in injuries of the orbit with preservation of the eyeball, 803–804.
Leclerq's appliance, 419.
Leclorinche and Vallee, polyvalent serum of, 35.
Leg, fractures of, 554.
Lens, opacification of the, 882–885.
Lesions of eyeball, 882 *et seq.*
Lesions of optic nerve, 859.
Loss of teeth complicated by fractures of alveolar border of mandible, 765.
Loss of vision after fall, 864.
Lower limb, esquillectomy of, 343.
multiple fractures of, 581.
Luxation of lens of eye, 885, 886.
Lyle's test for alkalinity of Dakin solution, 42.
Lymphagogic agents, 71 *et seq.*

Macular lesions, 833, 850-852.
Magnesium chloride, 74.
Magnesium hypochlorite solution, 65.
Magnesium sulphate, 86.
Magnus on effects of hæmorrhage, 865.
*Mal conitial*, 963.
Malar bone, elevation of the, 973.
injuries frequent, 811.
Malar canal, 792.
Malleolus, fractures of, 579.
Malocclusion, 636 *et seq.*
treatment of, 727 *et seq.*
types of, in united mandibular fracture, 652.
Malposition of jaw in old fractures, 620.
Mandible, apparatus for expansion of, 685.
fractures of, anterior; posterior; vertical, 599.
movements of, 592.
surgical advantages of, 593-595.

Mandibular fractures, stages of treatment, 629.
table of treatment, 670.
Mandibular lesions, immediate treatment of, 662.
Mandibular rigidity, essential for mastication, 592.
Martin, Claude, work of, 585.
Martin's formula, versus modern practice, 596.
Martin's principles, 590.
Mastication, dependent upon dental adjustment, 589.
Masticatory exercises, 670.
Maxillary antrum, lesions of, with orbital fracture, 948.
Maxillo - facial department, patients returned to army, 736.
Mechanical therapy, in joint wounds, cautions regarding, 32.
Mechanical treatment of fracture of mandible, 659.
problems of, 666 *et seq.*
Mechanism to bring forward posterior fragment, in fracture of mandible, 696-697.
Medulla, condition of, in fractures, 285.
Medullary canal, danger in, 315.
Membranes of eye, affections of, 886, 906, 917.
Menacho on "heridas orbito-oculares en cirugia de guerra," 787.
Meningitis, 967, 977.
Meningo-encephalitis, after fracture of orbit, 967-968, 972, 978-979.
Mental region of jaw, vascularization of, 690.
Metacarpal fractures, 182.
Metal splints, 368.
limitations of, 28.
Methyl violet, 86.
Missiles within joint, removal of, 11.
Mobilisation, 30.
Ollier's dictum regarding, 31.
Morestin, reparative operations by, 1004–1007.
Morphine in shock, 215.
Morrison's method (Bipp), 77.
Mortality statistics in wounds of face, 586.
Mouth-opener, mechanical, 732.
Moynihan's views on Bipp, 79.
Muller's muscle, paralysis of, 919–920, 922.
Multiple fractures of jaw, 620.
Multiple fractures of lower limb 581.
Multiple fractures of upper limb, 490 *et seq.*
Multiple joint wounds, 272 *et seq.*
Muscle destruction, 296.
Muscles dissociated by femoral fracture, 508.
Muscles, orbital ball in, 863.
traumatic lesions of, 879–882.
Mydriasis, 881, 887.
Myopia, 904–905.
Myotonic constriction, 654 *et seq.*
of maxillæ, mechanico-therapeutic treatment of, 730 *et seq.*

Nerve lesions, 290.
motor nerves, 854–856.
optic nerve, intra-ocular, 860–861.
Nerves, lesions of the sensory nerves, 856–857.
sympathetic nerves, 857–859.
Neuritis, optic, 901, 946.
retro-bulbar, 957.
Nové-Josserand's method, 476.

Occular complications of orbital fracture, treatment of, 983, *et seq.*
Old lateral fracture of mandible, 701.
Olecranon, fractures of, 136–137.
Ollier, arthrotomy, 207.
method, 13, 18.
orthopedic results, 244.
pelvi-cervical support, 194.
results, 143.
rugines, 23, 346.
Ombrédanne, method of, 476.
Operative indications, as regards age of fracture, 737.
Operative technic in
shoulder wounds, 112.
elbow wounds, 149.
wrist wounds, 175.
hip wounds, 190.
knee wounds, 216.
ankle wounds, 245.
foot wounds, 262.
fractures of humerus, neck o 389.
subdeltoid fracture, 402.
shaft of, 412.

Operative technic in
supra-condylar fracture, 435.
fractures of forearm above elbow joint, 445.
just above wrist, 462.
of shaft, 451.
fracture of shaft of radius, 470.
fracture of lower radial epiphysis, 479.
fracture of ulna, 486.
fracture of femur, sub-trochanteric, 497.
shaft, 514.
supracondylar, 550.
fractures of leg, shafts, 557.
of supra malleolar fractures, 572.
Operations, preparation for, in fractures of mandible, 739.
suitable time for, in fractures of mandible, 738.
on fractured mandible, details of technic, 742 *et seq.*
on joints, general technic, 18 *et seq.*
primary, 10.
secondary, 16.
Ophthalmia, sympathetic, 983 *et seq.*
Ophthalmia, sympathetic, enucleation of globe in, 945–946 (983–988).
treatment of, 986.
Ophthalmoplegia, total, 857-859.
Ophthalmoscope, shows lesions of eye after concussion, 1015.
Ophthalmoscopic examination. *See* Case Reports.
Optic atrophy, 843–844, 849, 858, 863.
Optic nerve, atrophy of, 817, 822, 828.
avulsion of, lesions of, 826, 852. *See* Nerves.
hæmatoma of sheaths, 865.
lesions of, 859.
behind entry of vessels, 862.
direct injuries, 862–863.
indirect, 863–865, 870-871.
retro-bulbar, 861–862.
Orbit, bones of the, 789.
fractures of the, dynamics of, 797–801.
etiology of, 802–806.
frequency of, 783–784.
history of, 776–787.
resistance of orbit to, 795–796.
protective role of, 793.
Orbit, bones of the, traumatic hæmorrhages into, 872.
vulnerability of, 798 *et seq.*
Orbital cavity, 788 *et seq.*
anatomy of, 788.
conformation of, 788 *et seq.*
margin and wall, fractures of the, 971–972.
resisting power of, 795 *et seq.*
Orbital cellulitis, 876.
death following, 878.
Orbital fractures, direct, do not occur by radiation, 809.
direct treatment of, 971.
implicating neighboring cavities, 976 *et seq.*
in war are direct fractures, 1015.
pathogenesis, 807.
reparative surgery in, 993 *et seq.*
Orbital margin and walls, inferior, external treatment of fractures of, 971 *et seq.*
internal, 970 *et seq.*
superior, 970 *et seq.*
Orbital muscles, paralysis of, 880–881.
repair of damage to, 997.
Orientation of mandibular arch, 670.
Orthopedic results, in fractures of astragulus, 243–244.
Os calcis, gunshot fracture of, 236.
Ostectomy, oblique, by Sébileau, 653.
Osteitis, focal, 12.
Osteogenesis, process of, 21.
Osteogenetic cells, death of, 307.
Osteogenetic layer, proliferation of, 20.
Osteomyelitis, 300.
Osteo-synthesis, in fracture of mandible, 734, 748 *et seq.*
Otis on orbital fractures, 784.
Over-riding of fragments, 291.
Ozone treatment of wounds, 93.

Panophthalmitis, 946.
Papilla, traumatic lesions of the, 860.
Paralysis, of external rectus, 928, 961.
of nerve of the eye, 856.
of orbital muscles, 880, 881.
Paramedian fracture of jaw, 606–608.
Paré, Ambrose, on injuries to eye, 778.
Parietal fracture, excision of, 11.

Pari-papillary rings, 865–866, 869, 870.
Patella, fracture of, 205.
removal of 217.
Pathogenesis of orbital fractures, 807 2.
Pathology of visual disorders, 849 *et seq.*
Pelvi-cervical support, Ollier's, 194.
Pelvi-pedial, casing, 195.
support (Bosquette), 525.
Percy's Manuel de Chirurgié d'armée (1792), quoted, 778, 779.
Periosteal regeneration, 145.
Periosteum, condition of, in fractures, 285 *et seq.*
infection of, 305.
Pes equinus, apparatus for correction of, 562.
Physiological features in:
fracture of humerus, neck of, 386.
sub deltoid fracture, 400.
shaft of, 407.
supra-condylar fracture, 433.
fractures of forearm above elbow joint, 442.
just above wrist, 460.
shaft, 446.
fracture of shaft of radius, 466.
fracture of lower radial epiphysis, 477.
fracture of ulna, 484.
fracture of femur, sub-trochanteric, 494.
shaft, 508.
supracondylar, 547.
fractures of leg, shafts, 555.
of supramalleolar fractures, 570.
Physiological incisions, 19.
Pigmentation, 900–901.
Pigmented ring in hæmatoma, 865, 867, 868, 869, 870–871, 872.
Pirogoff's tibio-tarsal disarticulation, 261.
Plaster appliances, 370 *et seq.*
continuous extension, 376.
errors in construction of, 374.
Plaster bandages, 426.
Plaster casing, for immobilizing, 28.
Plaster gait, 358.
Plugging, instead of drainage tubes, 349.
Polyvalent serum, 35.
treatment of wounds with, 98–99.
Position of foot, in fracture of thigh, 533.
Posterior fractures of mandible, 599.
Posterior tarsus, fracture of, 243.
Post-operative treatment:
of ankle wounds, 248.
of elbow wounds, 154.
of foot wounds, 266.
of hip wounds, 193.
of knee wounds, 218.
of shoulder wounds, 117.
Preparatory treatment in fractures of mandible, 675.
Proflavine, preparation of, 83.
Projectile, carrying clothing particles, 1.
direction of, in relation to orbital injuries, 813–814.
indirect lesions caused by, 905.
relation of, to visual disorders, 1016.
Pronation and supination in fractures of forearm, 440.
Prosthesis after mandibular fracture, 670.
Prosthetic methods, applied after fractures of orbit, with loss of substance, 1006 *et seq.*
repeated operations necessary for success, 1010.
Proteolytic phenomena, results of, 335.
Protovertebræ, absence of in cranium, 793.
Pseudarthrosis, 307, 399.
lateral, 714 *et seq.*
not caused by esquillectomy, 322.
of jaw, 650 *et seq.*
treatment of, 710 *et seq.*
of ramus of jaw, not affecting, mastication, 709.
with loss of substance, mechanism for, 724–726.
Pulmonary injuries accompanying shoulder wounds, 112.
Punctiform wounds, 278.
Pyoculture method, Delbet's, 36.

Radiating fractures, 808–810, 812.
with loss of sight, 864.
Radiation, not usual in injuries of orbital cavity, 806.

Radiography, in case-record, 816, 825–826, 830, 835–841, 843, 846, 849, 857, 900, 926, 932, 939, 943, 945, 947–948, 950, 954, 956, 963, 965, 967–968.
in cranial fractures, 805–806.
use of, in mandibular fracture, 642 *et seq.*
small value of, in fractures of the orbital vault, 972.
Radius, fracture of, 465 *et seq.*
Recovery of function, essentials for, 22.
Reduction, forcible, 355.
gradual, 356.
Reed-blind material, 569.
Repair of damage to orbital walls, 997.
Reparative surgery of fractures of orbit, 993 *et seq.*
"Reptilian jaw" deformity, 636.
Resection, 10, 12, 13, 17.
advantages of, 138–147.
after treatment, 156.
extensive, 109.
indications for, 26, 141.
of nerves of orbit, 857.
of shoulder, 109.
of elbow, 138.
of wrist, 179.
of hip, 189.
of knee, 212.
of ankle, 240.
of foot, 258.
sub-periosteal, 15, 389.
of ankle, 172.
supporting apparatus, after, 32.
in shoulder wounds, 106.
Rest, necessity of, in inflammation, 30.
period of, overdone, 31.
Restoration, of bony structures. *See* Grafts.
of mandibular arch, 670.
Retention bridges, use of, 693.
Retina, affections of, 907.
detachment of the, 828.
hæmorrhage, 829.
lesions of the, 853.
pure and mixed, 906–907.
lesions, varieties, 907.
total, 926, 931, 962.
traumatic detachment of, 915–917.
treatment of, 829.
treatment of traumatic detachment, 990–992.
Retina, double, 832–833.
by contact lesion, 834–835.
multiple traumatic lesions, 846, 848, 900.
Retinal detachment, operation of choice on, 991.
Retinitis, proliferans, 819, 824, 829–830, 901–903, 907–910.
proliferating, differentiation between, and choroido-retinitis, traumatic proliferating, 915.
traumatic, 915.
Rigidity of jaw, versus occlusion of teeth, 589–590.
Rohmer on orbital fractures, 786.
Rollet on orbital fractures, 786.
Rugins, of Ollier, 23, 346.
use of, 345.
Ruptures of sclerotic, not seen in war, 1017.

Salt pack method of wound treatment, 72.
Salt sacks, packing for wounds, 70.
Sauvez' therapeutic classification, in mandibular fractures, 673.
Sclerotic, rupture of the, 886, 893.
"Sébileau's serpent-jaw," 605.
Segmental theory of cranium, 794.
Sencert's appliance, 521.
Sepsis, 309.
Septic phenomena, suppression of, 106.
Septicemia, 297.
accompanying synovial injury, 2.
Serotherapy, 35.
Serum, polyvalent, 35.
treatment of Leclanche and Vallée, 96–97.
Shaft, fractures, causes of, from point of view of treatment, 277.
general study, 277 *et seq.*
produced by long-range bullets, 277.
Shock accompanying crushing of limb, 6.
accompanying fracture of femur, 514.
accompanying hip wounds, 188.
immediate treatment of, 333.
Shortening, due to vicious union, 545.
Shoulder, lesions, location of, 102.
wounds and fractures, anatomical types, 102.

Shoulder, wounds and fractures of, casings for, 120 *et seq.*
esquillectomy and sub-periosteal resection, 106.
evacuation of patients with, 124.
flail-like limb, after, 128.
operative technic, 112 *et seq.*
persistent sinus in, 127.
post-operative treatment of, 117 *et seq.*
practical steps in treatment of, 107, 108.
simple immobilisation of, 105.
treatment of patients seen late or after evacuation, 125 *et seq.*
types of, 103 *et seq.*
Sinuses and ankylosis, 169.
Sinusitis, 948, 950, 954.
Sling, apparatus, 379.
suspension, principles of, 367.
Socket of eye, artificial dilatation of, 996.
Soft parts, disinfection of, 343.
large loss of substance of, 623.
Soldiers resistant to eye infection, 890.
Sphenoidal fissure, 790, 855.
Splint, for wounds of knee, 220–221.
interrupted plaster, for fracture of both bones of forearm, 453.
laced, 32.
Splinters, 300.
extraction of, 971.
Stasis, pupillary, 963.
Sterilisation of wounds, surgical and mechanical, 35.
Strabismus, 928.
Subconjunctival ecchymosis, 876.
Sub-deltoid fracture, 400 *et seq.*
Subluxation of the lens, 885–886.
of eye, 885.
Sub-periosteal resection, 15.
Sub-trochanteric fractures, 494 *et seq.*
Sucker, india rubber, for plate for upper jaw, 661.
Sugar treatment of wounds, 75, *et seq.*
Suicide, gunshot wounds in, 806–807, 861.
Sunlight therapy, in joint wounds, 28.
Sunlight treatment of wounds, 90 *et seq.*
Supercilliary arch, restoration of, 932–933.
Superior orbital margin and well, fractures of, treatment, 971 *et seq.*
Superposition, accompanying lateral fracture of jaw, 612.
Supporting apparatus, 32.
Supracondylar fracture, 433.
Supra-malleolar fractures, 569 *et seq.*
Supra-orbital notch, 790.
Surgery, conservative, indications for, 275.
Surgical treatment of lesions of jaw, 734 *et seq.*
"Suro-metatarsal" cuff, of Ollier, 259.
Suspension apparatus, 380, 427 *et seq.*
for fracture of forearm, 454.
for fracture of leg, 561.
for fracture of thigh, 526–527.
for multiple fractures, 492.
in sub-trochanteric fracture, 500.
superstructure, 381.
Symblepharon, 967.
Syme's disarticulation, 247, 261.
Syme's operation, illustrated, 265.
Sympathetic, section of the, 921–922.
Synovial elements, destruction of, 21.
injury, complications of, 2.
membrane, damage, of, 2.
growth of, 20.
wounds of, treatment 8.
wounds of, types, 9.

Tampons of aseptic gauze, 28.
Tarlatan, use of, 372.
Tarsus, excision of, 259.
incisions used in resection of, 262.
Technics, older methods incompetent, 34.
Temporo-mandibular joints, mobility of, 698.
Tendo Achillis, bullet wound in, 234.
Therapeutic indications, primary, in shoulder wounds, 105.
elbow wounds, 134.
wrist wounds, 171.
hip wounds, 187.
knee wounds, 206.
ankle wounds, 238.
foot wounds, 256.

Thigh, amputation of, consequent on wounds of knee, 204.
Tibia, fracture of, 205, 574.
Toes, malposition of, avoidance of, 251.
Tooth, extraction, favoring union of fractured mandible, 625.
Toxic symptoms with joint infection, 3.
Tracheotomy, to be condemned, as means of relieving dyspnoea, 630, 664–665.
Transparent media of eyeball lesions of, 882.
Transplantation, 941, 944, 950, 953.
Traumatic hæmorrhages into the orbit, 872–879.
Traumatic lesions of extrinsic and intrinsic muscles, 879.
Traumatism of the ocular muscles, 879–882.
Travelling splints, 161.
Treatment, of fractures, 1 *et seq.*
of fractured mandible, elementary principles, 659.
Trephining, 960, 962, 963, 977.
Trigeminal nerve, lesions of the, 855–856.
Trochanters, fracture through, 186.
Trophic troubles, 925–926, 928.
Trough splints, 368.

Ulna, fractures of, 484 *et seq.*
Union of fragments important, in fracture of mandible, 671.
Upper limb, esquillectomy of, 343.
multiple fractures of, 490 *et seq.*
Uveal membrane, rupture of the, 893.
Uveal tract, affections of the, 886–887.

Vaccine and serum treatment of infected wounds, 95.
Vallee and Leclorinche, polyvalent serum of, 35.
Vascular injury, 289.
Vertebral theory of cranium, 793–794.
Vertical fractures of mandible, 599.
Vesical fistulæ, 187.
Vessels, lesions of the, 870–879.
Vibratory shock, a case of choroidal injury, 897.
Vicious callus, treatment for, 574.
Villain's apparatus for reduction of displaced posterior fragment of jaw, 702.
Villain's "crank" for use in pseudo arthrosis of jaw, 716, 717.
Vincent's method, technic, 88.
Vincent's powder, 35, 88.
Visceral lesions, 187.
Visual affections in injuries of the orbit, laws governing, 813–814.
Visual defects, nerve lesions, 854 *et seq.*
motor, 854.
sensory, 856.
sympathetic, 857.
Visual disorders, after orbital fracture, 1015.
pathology of, 849 *et seq.*
relation of, to projectile, 1916.
Visual lesions, according to direction of projectile, 813–814.
Vitreous body, hæmorrhage into the, 819, 958, 965.
Vulcanite plate appliance, 659 *et seq.*
Vulnerability of the orbit, 897–901.

Walls of the orbit, 796–797.
War fractures, always infected, 294.
War wounds, fundamental principles of treatment, 10.
muscle destruction in, 296.
White atrophy of optic nerve, 782, 786.
asepsis, present methods for, 34 *et seq.*
closure of, after Carrel-Dakin method, 52, 53.
treatment, modern, essentials of, 35.
Wounds and fractures of ankle, 234 *et seq.*
of elbow, 129, *et seq.*
of foot, 255.
of hip, 184, *et seq.*
operative technic, 190 *et seq.*
of knee, 201 *et seq.*
of the shoulder, 102 *et seq.*
diagnosis of, 102.
of wrist, 170 *et seq.*
Wright, Sir Almroth, physiological method, 35.
Wrist, wounds and fractures of, 170 *et seq.*
evacuation of patients after, 180 *et seq.*
operative technic, rules, 175–177.
post operative treatment, 177 *et seq.*

RC971 K43
4
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